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JOURNAL OF THE AMERICAN WELDING SOCIETY

VOLUME X | NOVEMBER, 1931 | NUMBER 11

Lest We Forget

Reprinted from Oct. 1, 1931, issue of Engineering News-Record.

The report of the structural steel welding committee presented to the American Welding Society at Boston will, as we had occasion to point out two weeks ago, exert a profound effect on the future of the art. In this country and probably in many foreign lands the committee's investigation will serve as the foundation upon which the further advance of structural welding will be built. For such a contribution the engineering profession is indebted to each and every member of the committee, but in greatest measure to its first chairman, the late James H. Edwards, who organized the work, gave to it his highest enthusiasm and energy, and carried it almost to fruition before his untimely death. It is important that Mr. Edwards' name be linked inseparably with this investigation and with welding research in general. There is need for keeping the standards for which he stood constantly before us. Structural welding is still in its infancy. Its development depends upon men with pioneering spirit, organizing ability, sane judgment, balanced viewpoint, and above all practical idealism. James H. Edwards reflected these qualities throughout his life, coupling with them a courage of conviction that either confounded the opposition or rallied it to his beliefs. Similar qualities will be needed to develop welding to its greatest utility. His name and his memory deserve to be perpetuated in the field where he pioneered so effectively.

Structural Steel Welding Profits by an Idea

Reprinted from July 25, 1931, issue of *Electrical World.*

In planning for the erection of the steelwork for the new Allied Arts Building in Lynchburg, Va., the designing engineer was faced with today's familiar problem—to weld or not to weld. There were 316 tons of steel to be installed; a first-class hotel stood directly across the street; costs must be kept low. Noisy procedures were to be avoided. By the exercise of considerable imagination and ingenuity electric welding was applied to the job with all-around satisfaction and notable economy.

For this job an erection seat was developed consisting of an element, shop-welded to the columns, into which connection angles, welded to the beam, are slipped. The loose connection is sufficiently firm to stay the columns until field welding can be done. This eliminates all, or virtually all, shop punching and, of course, the use of erection bolts.

Savings were substantial and the elimination of field bolts and punched holes played an important part in the economy. The price bid for the steelwork with welded construction, following this plan, was $1,975 less than for riveted construction of the same type. Resourcefulness and ingenuity have solved another problem in the application of electricity to the work of the world.

International Association for Bridge and Structural Engineering

The second meeting of the Permanent Committee of the International Association for Bridge and Structural Engineering was held at the Federal Polytechnical University, Zurich, on April 9 to 11. The aim of this association is to promote: International cooperation among scientists, engineers and manufacturers; the interchange of knowledge, ideas and the results of research work in the sphere of bridge and constructional engineering in general, whether in steel, reinforced concrete or another material.

Welding in steel structural work was one of the items discussed at this meeting.

A Correction to Article on "Yale University Group of Welded Buildings" in October Issue.

In the final paragraph of Gilbert D. Fish's article above named, credit was given various contractors engaged on the work. Due to a change in arrangements after the article was written, the field welding in the Hospital Unit was executed by the J. K. Welding Company, Inc., of New York City, as subcontractors to Palmer Steel Company. Churchward & Company, of New Haven, executed the field welding for the Briton-Hadden Memorial, not for both of the Palmer Steel Company jobs as previously reported.

Second Lincoln Arc Welding Prize Competition Has many Entries

(From News Release)

The Second Lincoln Arc Welding Prize Competition which will award $17,500 for the best papers on redesign for arc-welded construction closed Oct. 1, 1931, with four times as many papers entered as in the former contest sponsored by The Lincoln Electric Company of Cleveland, Ohio.

Reading and judging of the papers by a jury of award headed by Dr. E. E. Dreese, chairman of the electrical engineering department of Ohio State University, was begun Nov. 1.

Interest in this contest has been international in scope with 16 foreign countries represented, Germany, France, England and Australia submitting a remarkable number of papers.

Advertising— The Reader's Digest of Current Industrial Events

(Reprinted from November, 1931, issue of "Oxy-Acetylene Tips")

It has been said that it costs about 35 cents a copy to print *The Saturday Evening Post.* You buy it on the newsstand for 5 cents, or subscribe to it at a rate of less than 4 cents a copy. How can the publisher afford to sell his paper to you at these rates and still stay in business, much less make a margin of profit?

The answer is that the advertisements carried by the publication (and also by your own technical and business papers) make it possible for the publisher to give you editorially the things you want to read. The money you pay for your copy or your subscription actually, in most instances, simply pays for getting the book to you. It is the revenue obtained from the advertisers that pays for the production of the magazines.

Advertisers do this only because they are thoroughly convinced they have a story to tell that will be interesting and helpful to you. They believe there are facts about their particular company or products that you should know in order to operate your business most efficiently and profitably. They desire, of course, to increase their business by this means, but even this does not detract from the importance of the message to users of advertised products or services.

New developments in machinery or equipment, in distribution or price, are invariably announced in the advertising pages of periodicals. Changes in organization, in policy or in service that affect the use of commodities are always discussed in advertising space.

It is obvious, then, that to keep up to date in your industry you should read the industry's advertising.

You should have no hesitancy about

writing to advertisers for further information, in asking for booklets or any other descriptive material that may be offered, or in "sending back the coupon." Any material of this character mentioned in an advertisement (and much that is not mentioned) is prepared for your information and use, and advertisers are invariably glad to mail such material to any interested reader.

Study the advertising pages of your trade and business papers. They hold much information that will be valuable to you. They will keep you up to date in your own industry and offer you further opportunities for broadening your knowledge of subjects that will be interesting and helpful to you.

Purdue University Engineering Extension Department

The Engineering Extension Department of Purdue University announces its Seventh Annual Conference on Welding to be held at Lafayette, Indiana, on Dec. 10-11, 1931. The conference will consist of lectures, demonstrations and exhibits. Two hundred and seventy-five representatives from the industries of Indiana and neighboring states were in attendance at the conference last year. Requests for programs and other information should be made to Engineering Extension Department, Purdue University, Lafayette, Ind.

SECTION NEWS AND ACTIVITIES

BOSTON

An interesting program of meetings and inspection trips is being arranged for this season. On November 12, the Boston Section joins with other members of the Engineering Societies of Boston for a meeting on the "House of Magic." A lecture and demonstrations will be presented by L. A. Hawkins, Executive Engineer of General Electric Research Laboratory, and E. L. Manning, physicist. The meeting will be held in the main auditorium of Tremont Temple.

Plans are being made for an inspection trip to the Charlestown Navy Yard, to view an all-welded tug boat. The tug is sixty-five (65) feet long, and will be powered by a Diesel engine.

The second welded building to be erected in Boston is now under way. This building will be nine (9) stories high, and is a part of the City of Boston Hospital. Whereas the first welded building, a new fourteen (14) story office building of the Boston Edison Company, was shop riveted and field welded, this hospital building will be both shop and field welded. Although it is believed that fabrication by welding was decided upon for economic reasons, the fact that the steel work will be erected with the absence of the noise of riveting hammers, is an important advantage, giving the patients in nearby buildings a minimum of disturbance.

LOS ANGELES

The first fall meeting of the Los Angeles Section of the American Welding Society was held at the Pig 'n Whistle Cafe, Seventh and Flower streets, on Thursday, Oct. 15; there were 30 members and 10 guests present. The question of a proper meeting place for the Society was discussed, and Mr. Nyquist was requested to investigate the Frank Wiggins Trade School; Mr. Frank Longo was requested to find out about the Victor Hugo Cafe, and Mr. Paul Jeffers to investigate the University Club, and it was also suggested that the Mona Lisa Cafe be looked into.

The first talk of the evening was given by Mr. J. Desario, plant metallurgist for the Columbia Steel Company at the Torrance, Cal., plant. Mr. Desario gave a very interesting talk on the metallurgy of steel, describing the processes used in the manufacture of steel and the effects of various elements on the steel, particularly in regard to their effect on the weldability of steel. Mr. Desario's talk was followed by a general discussion.

The second speaker of the evening was Mr. Edward Fess, consulting metallurgist, who spoke on the metallography of steel. Mr. Fess had some interesting photomicrographs which he showed and explained to the members. We are greatly indebted to both Mr. Desario and Mr. Fess for an extremely interesting meeting.

Mr. C. W. Martin was made chairman of the committee to arrange the program for the next meeting. It was suggested that Prof. Maxstadt be invited to continue the discussion which he gave last year on the characteristics of electric generators.

PHILADELPHIA

At the meeting on Oct. 19 there were present about one hundred and fifteen people. Mr. H. M. Priest, assistant engineer, American Bridge Company, gave a very interesting talk on "The Welding of One-Story Structures."

For the Nov. 16th meeting it is planned to have Mr. T. W. Greene, of the Linde Air Products Company, present a paper entitled "The Lindeweld Process as Used for Pipe Line Construction."

There will be no meeting of the Section in December. The next meeting will be on Monday evening, Jan. 18, 1932.

PITTSBURGH

The 1931-32 seasonal activities of the Pittsburgh Section of the American Welding Societies were inaugurated Wednesday evening, Oct. 14, by a meeting held at the Fort Pitt Hotel which was attended by over 100 welding enthusiasts. The meeting was opened by A. M. Candy, general engineer for the Westinghouse Electric & Manufacturing Company, who gave a résumé of the papers presented before the Fall Meeting of the A. W. S. held in Boston during September. Mr. Candy ably handled a difficult assignment in reviewing the ideas and thoughts of other people. He briefly reviewed what took place during the meetings of the Structural Welding and the Welding Wire Committees. By means of slides and notes he reviewed as many of the papers that he could during the time allotted him.

Mr. Candy was followed by Dan Earl King, erection manager for the Pittsburgh Bridge & Iron Works, who presented a paper on The Welding of Yale University Bulidings as Seen by the Fabricator and Erector. Mr. King explained in detail the welding methods employed in the shop and in the field, told how the welders were qualified, how the work was inspected, described how several difficult erection problems were worked out and expressed some pointed views as to what should be done to further the progress of welding in this field. He also gave some data pertaining to lineal feet of welding per ton of steel, amount of beading laid down per man per day and similar equally interesting information which is often difficult to obtain. Mr. King stated that "so far 4000 lineal feet of ⅜-in. bead have been laid, every inch of which has passed inspection."

The meeting was concluded by a paper read by Charles H. Jennings, research engineer, Westinghouse Electric & Manufacturing Company, on the subject of "The Relief of Welding Strains by Annealing."

This paper covered an investigation undertaken to determine the effect of annealing on relieving welding strains. Three annealing temperatures were investigated and it was shown that the effectiveness of annealing depends upon the annealing temperature and the soaking time.

The proper choice of annealing temperature and soaking time is shown to reduce the residual welding stresses to within a few thousand pounds per square inch.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-146. Welding Engineer, college graduate, 18 years' experience in steel fabrication, last 6 years devoted exclusively to the application of electric welding; competent to handle any branch of the program of applying electric welding to the design, fabrication and erection of structural steel and ornamental iron.

A-147. Welding Engineer, experienced in quality shopwork, inspection. Can cooperate with engineering department for developing correct designs for economical welding. Invites employment for limited period.

A-148. Gas Welder. Two years' experience with G. E. Co.

Pullman Builds All-Welded Hopper Cars for the C. G. W.

✦Substantial saving of weight in five 70-ton cars devoted to increased revenue load-carrying capacity.

(This article was reprinted by special permission of Railway Age)

WITH the primary object of developing a coal car to produce more revenue per pound of weight on the rails, the Chicago Great Western consented to have five units of its orders for 300 70-ton hopper cars, placed with the Pullman Car & Manufacturing Corporation in the latter part of 1930, built to a design proposed by the car builder and embodying, among other features, practically all-welded construction. These cars, recently completed and delivered to the railroad, weigh 45,900 lb. each, or roughly only as much as 50-ton cars of riveted construction. This means that 20 additional tons of coal can be carried in each car at no greater transportation expense for the movement of tare, or dead weight.

On the basis, both of reduced light weight and of increased capacity, the welded car shows marked superiority. With a light weight of 45,900 lb., it provides a cubic capacity (level full) of 2863 cu. ft. As compared with the heaviest welded car in the accompanying list of typical 70-ton hopper cars of recent riveted design, the welded car weighs 10,500, or 18.6 per cent, less, and at the same time provides 85 cu. ft., or 3.1 per cent, greater cubic capacity, all of which is available for carrying increased revenue load. As compared with the lightest riveted car in the list, this is a decrease of 4300 lb., or 8.6 per cent, in light weight, a notable reduction, in view of the fact that a gain of 243 cu. ft., or 8.9 per cent, in cubic capacity is made at the same time. On the basis of $100 increased earning power per car per ton per year, it is anticipated that the 70-ton welded car will produce, on the average, $400 more revenue per year than one of equal nominal capacity but incorporating ordinary riveted construction.

The Chicago Great Western 70-ton welded hopper car is of the conventional three-hopper type, with standard four-wheel trucks and 6-in. by 11-in. journals, but the body design is a distinct innovation, no cars having previously been built with the type of construction and amount of welding used in these cars. The entire body of each car, including a one-piece welded tubular steel center sill, is assembled by welding, and the only rivets used are those for fastening safety appliances, draft-gear supports, door hooks and similar parts subject to breakage or periodic removal. Even the pipe joints are made by welding, and that process is used to attach and anchor the train line and connecting pipes to the car body.

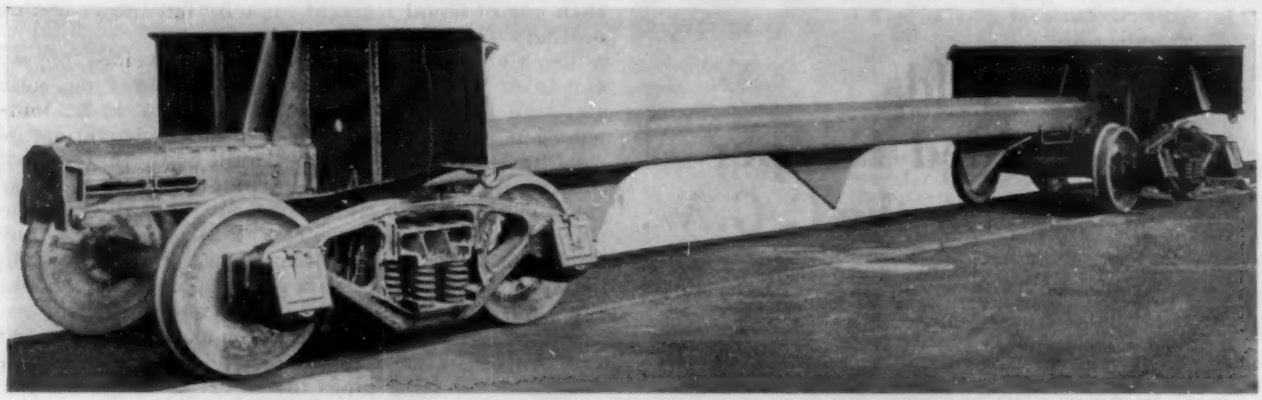
Typical 70-Ton Hopper Cars of Comparatively Recent Design

Road	Light Weight	Capacity, Cu. Ft.	
		Level Full	10-In. Heap
New York Central	50,200	2,620	2,948
D. L. & W.	50,800	2,755	3,062
N. & W.	51,500	2,439	2,729
C. G. W.	52,675	2,778	3,100
C. M. St. P. & P.	52,800	2,778	3,100
C. & N. W.	54,900	2,590	2,900
I. C.	56,400	2,778	3,100
C. G. W. (all-welded)	45,900	2,863	3,197

Both oxyacetylene and electric arc welding are used in the manufacture of these cars; the former on the heavier sections where strength and ductility of weld metal is the prime essential, and the latter on the light sheets where the lower heat of the arc reduces the probability of warpage.

There are approximately 1500 lineal feet of welding in the car. Of the 200 lb. of welding rod required, 56 per cent is deposited by the oxyacetylene process and 44 per cent by the electric arc. The former method is used for the following parts: Center sill and all attaching parts; body bolster and all attaching parts, including side and floor sheets; all-pipe cross ridge; lower end construction; floor sheets, except where joined to the side and end construction; all pipe joints and pipe anchorage. The following parts are welded with the electric process: All side-sheet construction; all upper end construction; all dump doors. The Oxweld Railroad Service Company cooperated with the Pullman Car & Manufacturing Corporation in refining design details to meet the welding requirements and in the supervision of the performance of the actual welding operations.

One of Five All-Welded Hopper Cars Recently Built by the Pullman Car & Manufacturing Corporation



All-Welded Tubular Centersill and Bolster Construction Used in New Chicago Great Western Hopper Cars

Welding Operations Checked and Cars Tested

Before beginning welding operations on the new cars, extensive tests, covering a period of several weeks, were made to determine the relative efficiencies and costs of various types of welded construction required in the fabrication and assembly of the car parts. Experienced operators were used for both the oxyacetylene and for the electric welding operations, these operators being required to submit test specimen welds at intervals as a check on the quality of their work. In addition, all welds were hammer tested during the course of construction, with two objectives, namely, to distribute local stresses and to permit the immediate correction and reinforcement of any welds which gave indications of weakness.

General Dimensions of Chicago Great Western All-Welded 70-Ton Hopper Car

Length over strikers	42 ft. 0 in.
Length over end sills	41 ft. ⅜ in.
Height, rail to body center plate	2 ft. 2¾ in.
Side bearing centers	4 ft. 2 in.
Distance between truck centers	32 ft. 0 in.
Truck wheel base	5 ft. 8 in.
Length inside	41 ft. 0 in.
Width inside	10 ft. 2⅝ in.
Width over side sheets and overall	10 ft. 2¾ in.
Height, rail to top of side plate	10 ft. 8 in.
Cubic capacity level full	2,863 cu. ft.
Cubic capacity with 10-in. average heap	3,197 cu. ft.
Light weight of car	45,900 lb.
Revenue load with 10-in. average heap	164,000 lb.
Total weight on rail	210,000 lb.

Upon the completion of each car, it was painted with a cement wash, which was permitted to dry, and the car was then loaded with sand until its total weight on the rails was 210,000 lb. This load filled the car only to within 10 in. of the top, consequently being concentrated over a smaller area than would be the case with coal loading and introducing stresses in excess of any likely to be encountered under normal operation. A careful examination of joints gave no indication of the cement's flaking off, due to working of the joints or movement of the plates.

In addition to this practical test for stresses beyond the elastic limit, the loaded car was thoroughly tested with extensometers to measure the elongations and to determine the relative stresses within the elastic limit, encountered in various car parts. The use of the extensometers showed uneven stresses in certain parts of the car on the first loading, as, for example, around the bolster, which was reinforced and another test made. Certain plates also showed excessive stress on the initial loading, which was equalized on subsequent applications. As finally tested, each car showed a reasonably uniform distribution of stress not exceeding 9000 lb. per sq. in. in all parts of the car, including the underframe, bolsters, side sheets, end construction, slope sheets, hopper doors, etc.

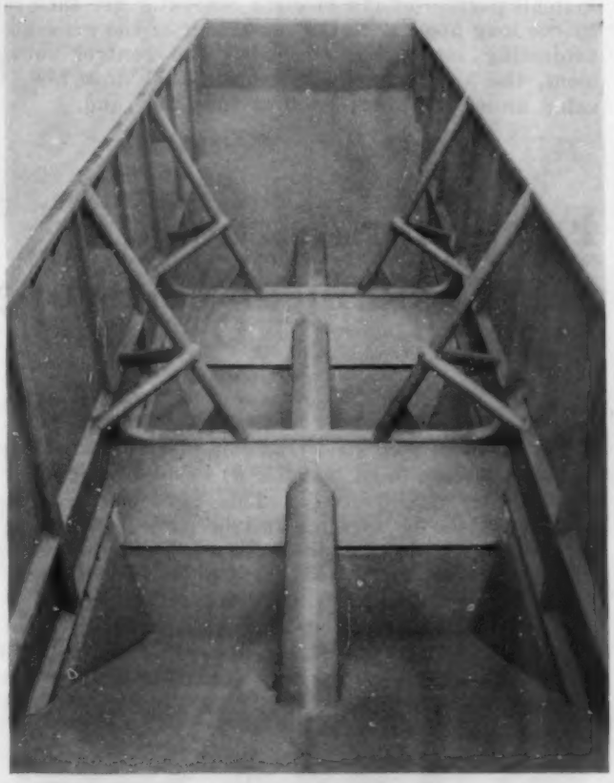
Following the static load test, an impact test was made, each car being brought up to a speed of 5½ m.p.h. and allowed to collide with a second car, similarly loaded, but with the brakes lightly set. No noticeable permanent effect on the structure of either car was apparent.

General Method of Construction Employed

The welded hopper car is designed to take advantage of the welding to tie in all members so that all parts of the underframe and superstructure act as a unit in resisting draft, buffing and load stresses. Pressed shapes, with large radii at the corners, are used, these shapes lending themselves to the welded construction much better than the usual structural shapes, and having the additional advantage of being light in weight. When welded to the sheets, they form box sections of greater strength per unit of weight than the usual structural shapes used in riveted cars. Flanges are largely omitted, not being required for the application of rivets. The stakes are placed inside the car and the side sheets brought out to the line of the riveted car to give maximum capacity. This construction requires the corners at the side ladder to be offset inwardly to provide clearance for the ladder. At the end opposite the ladder, the side is carried straight out to the corner without any offset. The car is designed to be self-clearing in every respect, the absence of rivets contributing effectively to this feature. All joints in the coal space are made with continuous welds so that there are no openings to permit the entrance of moisture and dirt and promote corrosion. In addition, the slope sheets are given a pitch of 1¼ in. from the sides toward the center, in order to drain water away from the corners where the corrosion takes place. This construction also tends to keep the center of the load moist and assist in unloading.

The body bolster is built up with a bottom cover plate and a web plate with proper flanges at the top for supporting the floor sheets. The sides are made of two sheets, joined with a continuous butt weld for their entire length. This provides a heavy sheet where the corrosion and hammering is most severe and saves considerable weight where the greater thickness is not required.

The side sill is formed of a plate in a channel shape in one piece from bolster to bolster. An intermediate side sheet stiffener is formed in channel shape of the same section as the side sill, being lo-



The Interior Construction of the All-Welded Hopper Car—Patents Are Pending on a Number of Features Embodied in the Construction of These Cars

cated at the joint between the upper and the lower side sheets. The side plate is formed in much the same shape as the side sill, but, in this case, the top flange is straight and the lower flange is sloped downwardly. The side plate is continuous the entire length of the car, being joined to the side sheet with intermittent welds.

The side stakes are formed in channel shape, seven per side. All but the bolster stakes are rectangular in section. The bolster stakes have their flanges toward the end of the car at an angle to provide for clearing the lading.

The cross ridge extends across the car in one piece, with a gusset pressing of approximately the same cross section at the sides. The cross ridge gusset is formed of 4-in. standard pipe, extending from the side plate through the cross ridge to the center sill. Longitudinal bracing is provided by two pieces of 4-in. pipe at 60 deg., extending from the side-sheet stiffener to the cross ridge gusset.

The corner posts are structural angles joined to the end and side sheets with intermittent welds on the outside and continuous welding inside the car. The end posts are structural channels joined to the end sheet with continuous welding. The end sill is a structural angle welded to the center sill and to the end and corner posts.

Three hopper doors are provided per car, instead of six, as is the usual practice. Each door is made of ¼-in. steel plate, with channel-shaped stiffeners welded to it with intermittent welds. The doors are arranged for the application of hooks for holding them in the closed position. The hopper-door hinge is a new type, being continuous from the side to the center sill on each side of the car.

An All-Welded Locomotive

By B. S. HAVENS

✦ Mr. Havens is connected with the General Electric Co. News Bureau.

SEVEN all-welded locomotives have been constructed by the General Electric Company for switching service at Bush Terminal, New York City. While the engines and electric equipment follow the usual standards of design, many new features are incorporated in the framework because of the use of welding.

Fig. 1—Oil Electric Locomotive

The complete structure of cab, under-frame and trucks is fabricated entirely from structural steel shapes and plates, and is arc welded throughout. There are no rivets, and bolts have been used only for those portions requiring occasional removal or renewal.

Each locomotive is of the 60-ton type and has a Diesel-electric power plant, using a 300 hp. Ingersoll Rand Engine. The truck frame consists essentially of three members: two side frames of 26-in., 151-lb. girder beams with a 22-in., 108-lb. girder beam serving as the bolster. The bolster beam is welded directly to the side members, the joint surfaces being

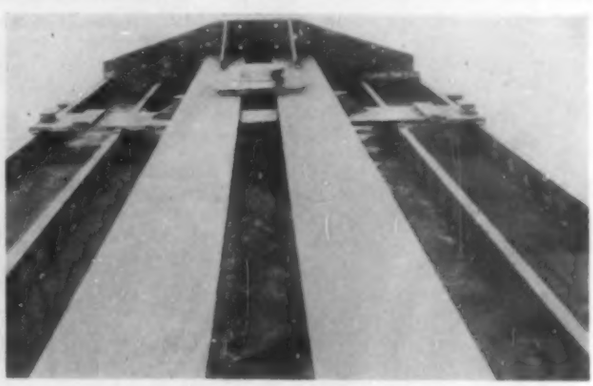


Fig. 2—All-Welded Underframe of Steel Plates and Structural Beams

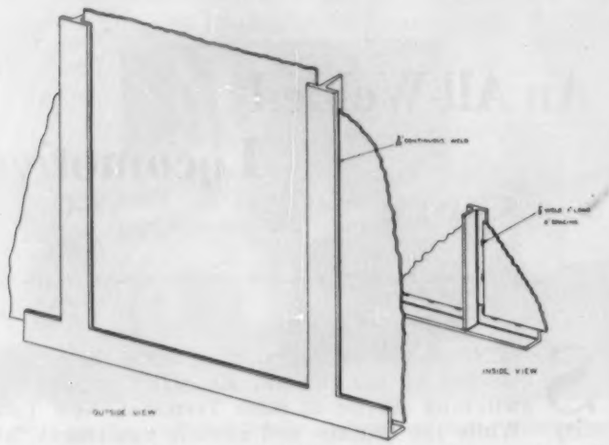


Fig. 3—Detail Showing Cab Wall Construction

reinforced with heavy gusset plates and brace plates. All welds are continuous and, except at a few minor points, all welds on the truck were made with a heavily-coated electrode. Load is carried to the journal boxes through double equalizer bars located on either side of the girder beam web. Load is transmitted to each bar through four helical springs. The platform or under-frame has two 14-in. 100-lb. "H" columns for center sills with intermediate and side sills of 6-in. channel. The engine is mounted directly on these center sills so that, in addition to taking the buffing stresses, they afford also a rigid support for the power plant. For the end sills 1½-in. plates are used. A ⅜-in. deck plate extends over the entire platform and is attached to the longitudinal sills by ⅜-in. intermittent welds on a 10-in. pitch. End plates are attached by ¾-in. continuous welds. Body bolsters are attached to all four sills by ¼-in. continuous welds.

The cab structure consists of a framing made of 2-in. Tee sections with continuous welding at all joints. The side and roof sheets are attached to this structure by intermittent welds on a 6-in. pitch, except at the outer surface of the side sheets where, in order to provide water-tight joints, continuous welds are employed. The side sheets are placed inside the framing. This permits tying the edge of the sheet at two places: the intermittent weld on the inside and the continuous weld on the outside. In addition, the backs of the Tee section, projecting through in this manner produce a paneling effect in the cab wall and break up what would otherwise be a monotonously plain surface.

Instead of the usual box cab which has heretofore characterized most Diesel-electric locomotives, a modified steeple or hood type cab is used. The engine and a small portion of the electric generator are inclosed by the long hood, with the remainder of the generator projecting into the main cab. The control equipment, the air compressor and the fuel tank are located under the short hood at the other end.

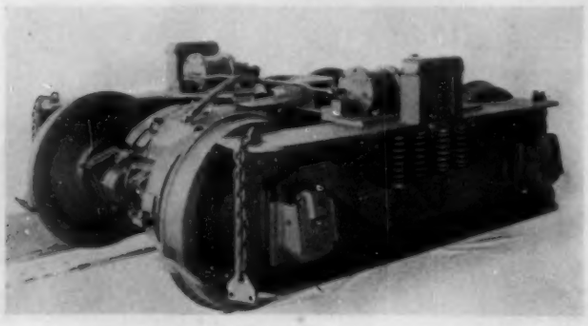


Fig. 4—All-Welded Truck with Motors Installed

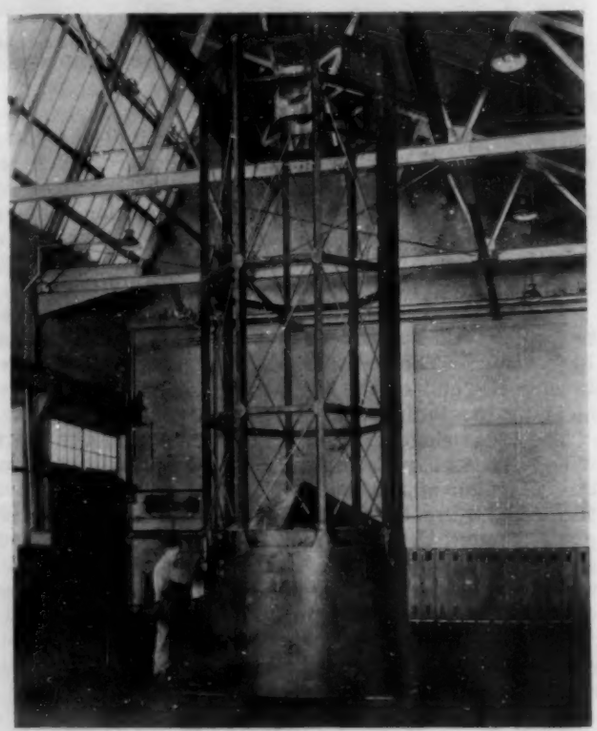
Frame for Astronomical Telescope

By **A. F. DAVIS**

✦ Mr. Davis is Vice-President fo The Loncoln Electric Co.

FIRST arc welded steel frame or tube for astronomical telescope to be installed at Perins Observatory, Ohio Wesleyan University. This telescope provides for the first large telescope mirror made in America. This 69-in. mirror was produced by U. S. Bureau of Standards.

The tube is about 25 ft. long and 6 ft. in diameter. Welded steel construction was used to save weight, reduce cost and give a structure with a minimum of deflection. The telescope was manufactured by The Warner and Swasey Company, utilizing the arc welding process.



All-Welded Telescope Frame

Structural Steel Report

THE structural Steel Report, which is being published in serial form in the JOURNAL, is also available in book form. The book contains 208 printed pages. Price $1.00.

Modern Electric Resistance Welded Pipe

By J. S. ADELSON *and* L. B. GRINDLAY

✦Paper presented at June 9, 1931, joint meeting of the Metropolitan Sections of A. S. C. E., A. W. W. A., and A. W. S., by J. S. Adelson, Chief Metallurgist, Steel Tubes, Inc., and L. B. Grindlay, Manager, Metallurgical Dept., Youngstown District, Republic Steel Corp.

INTRODUCTION

THE tubular and pipe industry, the same as other lines of manufacture, has made rapid strides to improve the product and method of manufacture. Electricity for use in welding has been used very extensively and has ultimately been successfully applied to the welding of tubes and pipe. The particular welding process with which we are here concerned is a special modification of electric resistance welding developed for this purpose. It is covered by the Johnston and other patents and is

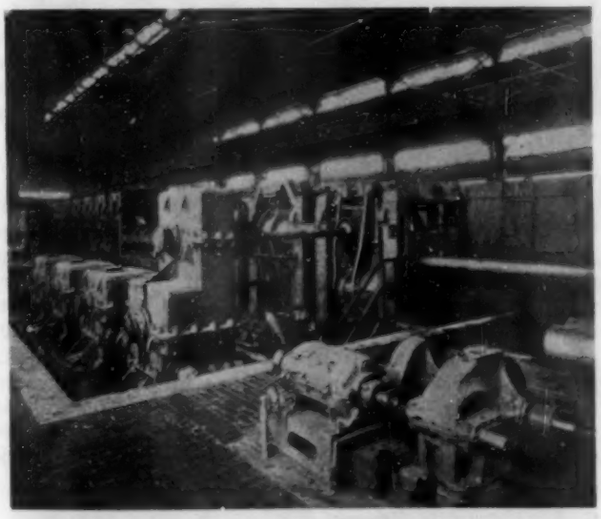


Fig. 1—Forming Equipment

owned by Steel and Tubes, Inc., a subsidiary of the Republic Steel Corporation, who has used them in the manufacture of mechanical tubing for about twelve years. Several years ago the parent company applied this process to heavy wall and large diameter pipe. A welding unit was built to weld these larger sizes and the results were so satisfactory that three large units have since been installed at a cost of $10,000,000.

Method of Manufacture

Strips or plates are the basic materials used in the process and the long lengths with specially prepared surface and sheared or machined edges to accurate width, are passed through a series of forming rolls. From these the originally flat steel emerges in tubular form with the longitudinal edges accurately butted. Figs. 1 and 2 are photographs of the forming equipment. In Fig. 1 the tube can be seen as it leaves the last pass.

Fig. 2—Forming Equipment

The butted tube or pipe is then propelled through the massive welding unit, which is shown in Fig. 3. The butted pipe ready to be passed through the welding unit can be seen on the conveyors on the right-hand side of the photograph. An idea of the magnitude of the welding section can be obtained by comparison with the one-story office at the extreme left of the photograph, and slightly to the left of the main welding section. The welding unit consists of a pair of circular electrodes which make continuous contact with the butted tube on each side of the seam. There are also supporting rolls in this unit which assist in applying pressure at the instant that the metal is heated to the welding temperature. Alternating current of comparatively high amperage and low voltage is generally the source of heat. The usual speed of welding is from 40 to 60 ft. per minute.

The main feature of the process is to correlate the four factors involved in continuous welding, namely, speed, temperature, pressure and contact so as to confine the heat to the edges only.

After welding the tube or pipe must pass through sizing or straightening rolls which can be seen in Fig. 4. Then as routine procedure, the pieces are inspected and ends are sawed off and tested by crushing or expanding. In the case of tubing, the product is then fabricated to meet the trade requirements and can be produced in various shapes. In the case of pipe the ends are trimmed, threaded or beveled for field welding and then tested under hydraulic pressure while pneumatic hammers automatically jar the pipe near the line of weld.

Characteristics of the Product

1. *Long Lengths*

Because of the continuous method of manufacture, the tubing can be supplied in any desired length or in

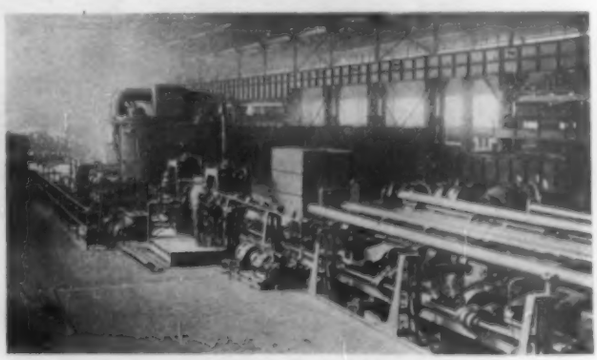


Fig. 3—Welding Unit

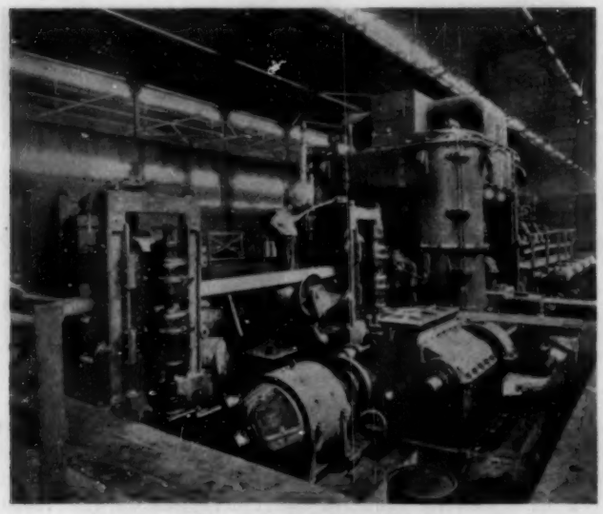


Fig. 4—Straightening Rolls

Fig. 5—Illustrating Vanstoning Quality of Electric Welded Pipe

coils. The length of the pipe is governed principally by facilities for shipping and convenience in handling.

2. *Uniformity in Wall Thickness*

Because of the ability to roll strip or skelp with only a slight variation in thickness across its width and due to the fact that the tube or pipe is formed cold there is a resulting freedom from thin wall areas such as encountered in other methods of pipe or tube manufacture.

Fig. 6—Illustrating the Bending and Oxy-Acetylene Welding of Electric Welded Pipe as Carried Out in Accordance with Regular Shop Practice

3. *Surface*

Tubing can be made of cold rolled strip steel which has a smooth, scale-free surface. A clean surface is available in pipe for gasoline transportation.

4. *Greater Resistance to Corrosion*

The general opinion as concerns the subject of corrosion is that the worst form of corrosion, namely, pitting, is directly affected by the variation in scale on the material subject to the corrosive action. As applied to tubing and pipe, this means that a clean product such as our electric weld tubing or pipe will offer greater resistance to corrosion than furnace produced pipe which necessarily has scale, mostly irregular, and the particular spots where the amount of scale varies, are the places where the corrosion concentrates, thus causing pits at these spots.

5. *Weld Sound and Ductile*

The weld is remarkably free from slag and oxide inclusions because of the clean cut edges and surface which are not given a chance to oxidize during the welding operation. The structure of the welds in Republic pipe or tubing is that which is found in heat-treated steel. This is because of the rapidity of application and dissipation of the heat which prevents grain growth at or adjacent to the weld which would tend to decrease ductility and strength. The weld is slightly stronger than the balance of the wall of the tube or pipe but still has ample ductility for fabrication.

6. *Regularity of Product*

Regularity and uniformity of product is attained because all the factors involved in manufacture are

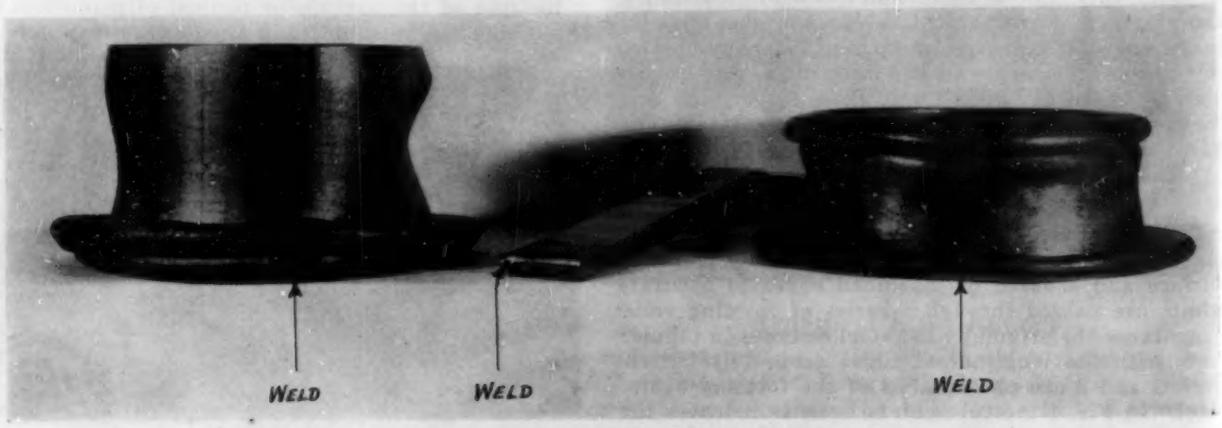


Fig. 7—Ductility Tests on Electric Welded Pipe

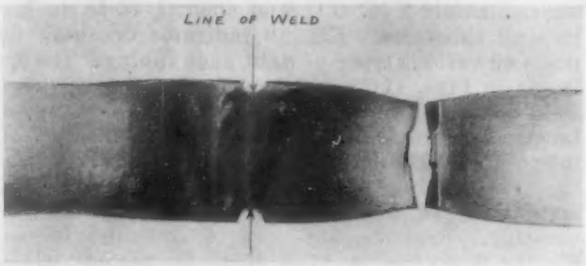
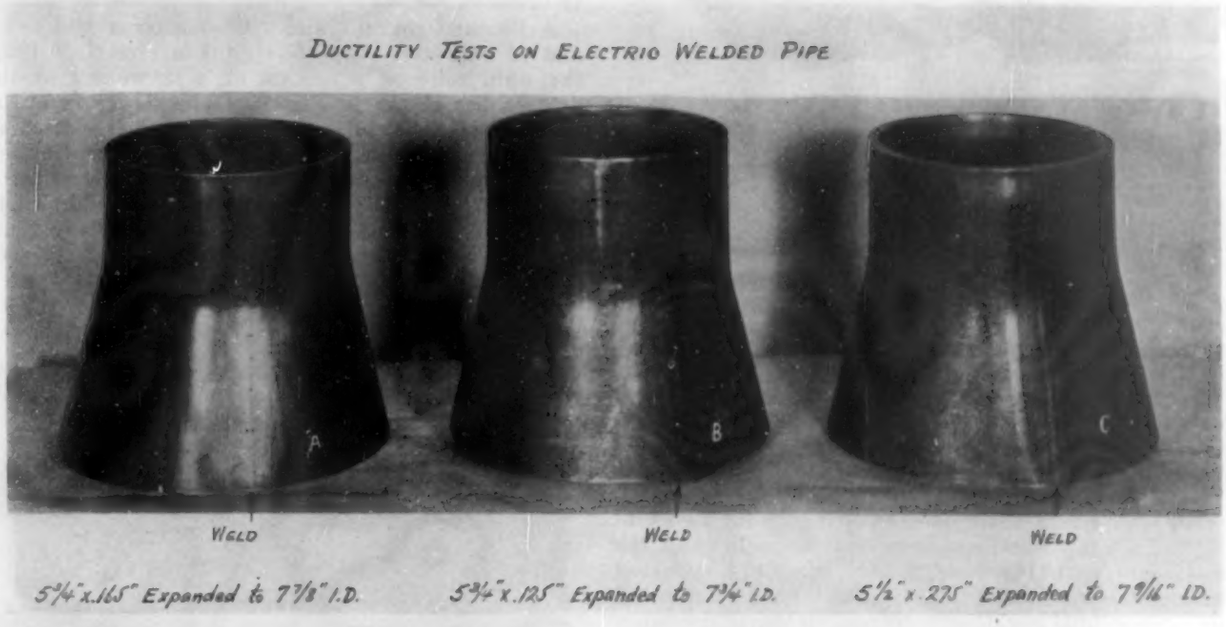


Fig. 8—At Left Tensile Test with ⅛" Dia. Notch at Weld, Illustrating the Fact That the Electric Weld Is 100% Efficient. Figure Below Ductility Test



under absolute control, thereby differing from pipe fabricated under variable furnace and operating conditions which cannot be standardized.

Testing and Microscopic Studies

In the development of any new process very close contact with the product must be maintained to insure consistency in quality. This fact was fully appreciated by our organization and various tests, abusive in nature as well as standard, were and are still employed in testing this material. Photos Nos. 5-6 clearly illustrate how perfectly our electric resistance welded tubing and pipe meets practical requirements for ductility, such as bending, coiling and van stoning. The pipe in Fig. 7 has been subjected to crushing and flattening tests. The severity of the

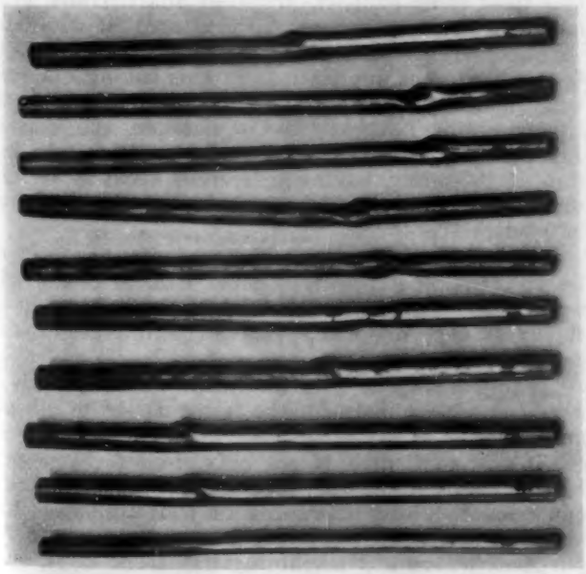


Fig. 9—Tubes Tested in Torsion

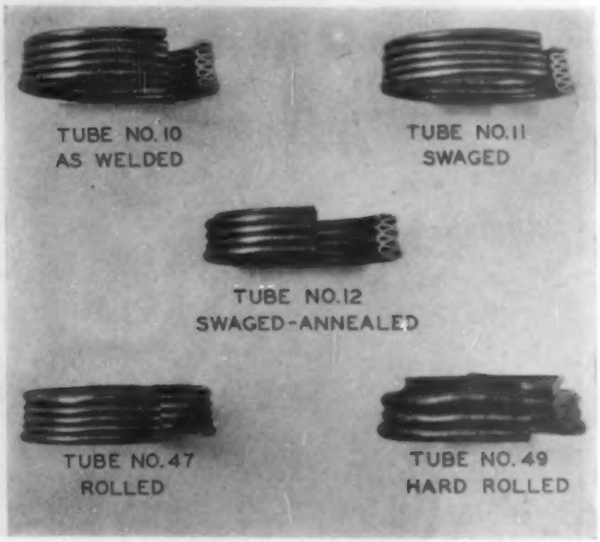


Fig. 10—Crushing Tests on Light Gage Tubing

Fig. 11—Ductility Tests on Electric Welded Pipe—Twist Test with Weld at Right Angles to Axis of Test Strip

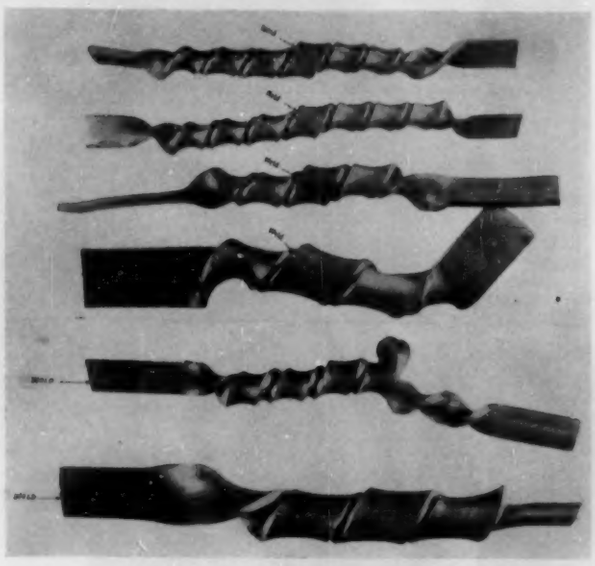


Fig. 12—Lower Two Figures—Twist Test with Weld Parallel to Axis of Test Strip

operation has not caused the weld to open. The expansion tests in Fig. 8 are a conventional method used for testing pipe manufactured by this process. The other photo in Fig. 8 was taken of a tensile specimen which had been notched at the weld so as to make the cross sectional area of the specimen at the weld less than the base metal. Fracture occurred outside the weld. The tubes in Fig. 9 have been tested in torsion until buckling occurred. None of the tubes show any sign of failure at the weld. Tubes were all

Fig. 13—A Hydrostatic Test of Tube to Destruction

approximately 2 in. O.D. and about 1/16 in. to ⅛ in. in wall thickness. Fig. 10 indicates crushing tests made on various types of light gage tubing. The specimens in Figs. 11 and 12 have been twisted with the weld both transverse of the specimen in one case and longitudinal in the other. In neither case has the tube failed. The hydrostatic pressure used in testing the tubes in Fig. 13 has been in excess of the ultimate strength of the steel resulting in the tubes bursting. Fracture has occurred outside the weld. Fig. 14 is a close up view of a pipe tested similarly to those in Fig. 13.

A Photomicrograph and a Photomacrograph at 250 and 12 diameters respectively taken directly through the weld zone on a section of pipe welded by this process are shown in Fig. 15. The structure at and adjacent to the weld is well refined and free from abnormality found in pipe welded by other methods. Microscopical examination also shows the localization of the heat to a very narrow zone at the weld. Photomicrographs in Fig. 16 illustrate the structure found in furnace butt weld pipe as compared with the normal structure in the body of electric welded pipe.

Uses

Some of the innumerable uses of this product may be of interest. Take our automobile, for example,

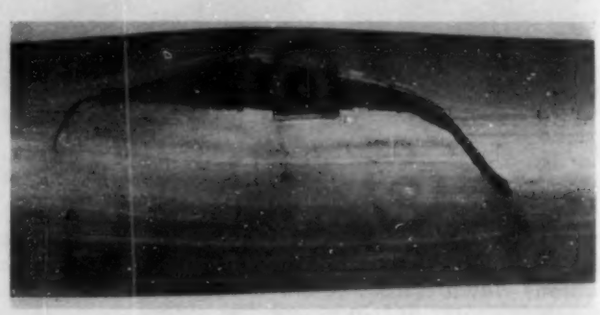


Fig. 14—Close-Up View of Hydrostatic Test to Destruction

and consider the number of parts made of mechanical tubing, such as steering column, water manifold, control tube, lamp support, propeller shaft, frame cross member, torque tubes, etc. Furniture, bicycles, conveyors, and tubing for refrigerating systems are a few of the other applications of this tubing. A light wall threadless galvanized conduit approved by the Underwriters Laboratories is now on the market. Among its advantages are ease in handling, elimination of threading, saving in freight because of light weight, also the rapidity with which installation can be made.

The large diameter pipe is used for gas and oil lines. This pipe is made in sizes 4 in. to 16 in. O.D., with a minimum gage of 1/16 in. and a maximum thickness of ½-in. wall. Heavier wall pipe, though, can be made.

Up to the present time 4500 miles of this pipe is in actual service, chiefly for the transmission of oil, gas and gasoline.

Electric weld pipe is not only used for line pipe but for many other purposes, due to the fact that it conforms to close tolerances in wall thickness and size. This feature makes it especially adapted for purposes where any machining has to be done, such as lifts for hoists, idle rolls and plungers.

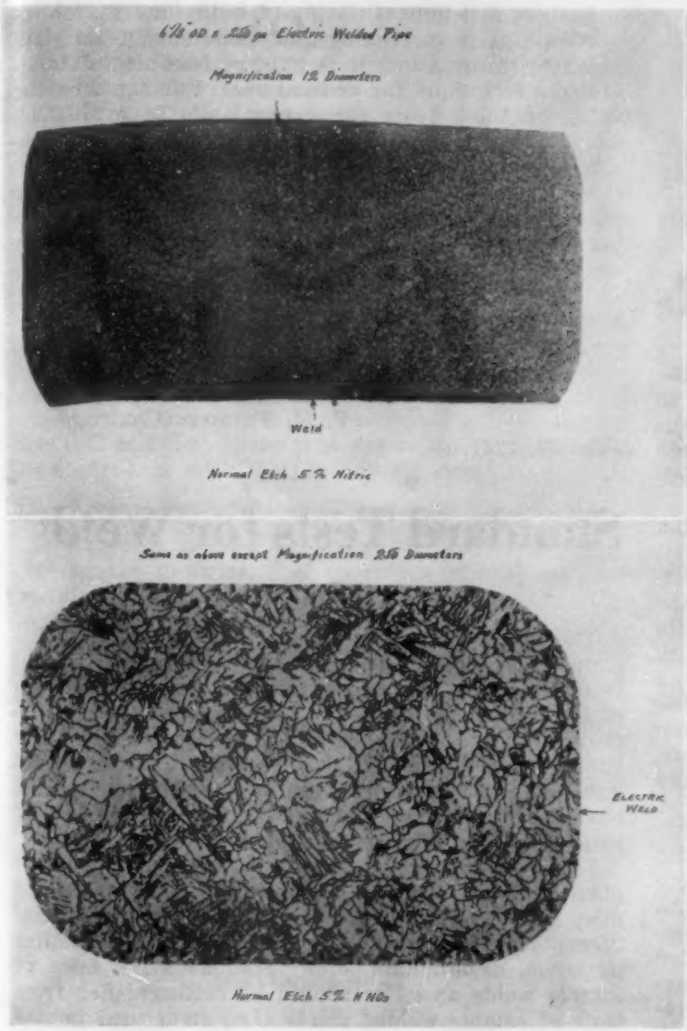
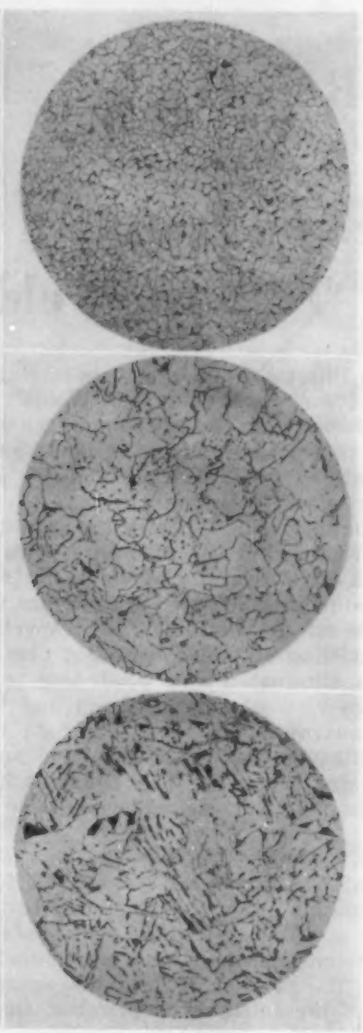

6⅝ OD x .280 ga Electric Welded Pipe
Magnification 12 Diameters
Weld
Normal Etch 5% Nitric
Same as above except Magnification 250 Diameters
Electric Weld
Normal Etch 5% HNO3

Fig. 15



254
Normal Structure Body of Electric Welded Pipe. 100 Diameters

595
Normal Structure Butt-Welded Pipe. 100 Diameters

93
High Heat Structure Butt-Welded Pipe. 100 Diameters

Fig. 16

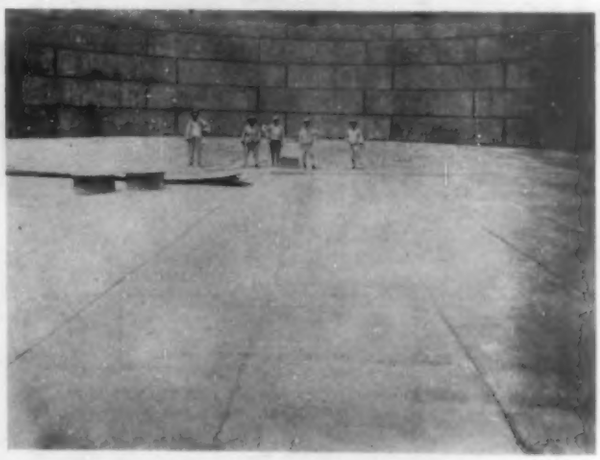
Tubing and pipe manufactured by this process can be obtained with varying carbon content up to .50, and in a number of alloys such as nickel, chrome nickel and chrome molybdenum steels. Tubing is also available in the stainless 18-8 alloy, known as Enduro KA-2.

Welded Floors of Large Oil Storage Tanks

By YUE SANG CHING

✦ Mr. Yue Sang Ching is connected with The Yuen Chong Tai Iron Works of Shanghai.

YOUR readers will be interested in the photograph shown of the first arc welded floating roof which we have recently welded. This is of interest because of its large size and continuous welding and the care which had to be taken to avoid buckling. This tank was made for the Shell Oil Company of California in the interests of the Asiatic Petroleum Company. The picture illustrates the deck floor after it was laid on trestles and tack welded. Great care was taken to get the 3/16-in. plates as flat and level as possible before welding continuously. It is a characteristic of the Chinese worker to be very painstaking and careful. Covered rods were used as it has been found to give better work and is more readily applied.



Report OF Committee on Standard Tests for Welds

THE American Bureau of Welding issued Bulletin No. 1 on "Standard Tests for Welds" in June, 1921. Over a year ago this committee was requested to review this bulletin and recommend such revisions as are justified by experience and the advancement of the art since its promulgation.

The revision of bulletin No. 1 proved to be not a simple matter. As reported at the 1930 annual meeting of the Bureau, a wide diversity of views on testing of welds was found outside as well as within the committee. Opinions differed not only with respect to the details of the existing standard tests but also as to which should be eliminated and what new tests should be added. In view of this situation and the increase of competent opinion during the past ten years, the committee concluded that a broader discussion of the subject was necessary than could be had within the committee or by correspondence outside of the committee.

It was, therefore, proposed to the Meetings and Papers Committee of the American Welding Society that a symposium on this subject be included in the program of the fall meeting at Chicago last September. Such a symposium was held and an extensive discussion was had, the printed proceedings occupying about 70 pages of the JOURNAL (September, October and December, 1930).

The committee, after due consideration of this discussion, has prepared the accompanying revision of Bulletin No. 1 "Standard Tests for Welds" and recommends that these revised standards be approved.

The principal changes that have been made are the elimination of the fatigue test and the impact test, the complete revision of the bend test and the inclusion of a shear test.

Fatigue and impact testing of welds in research investigations is increasing and while such tests yield valuable information, it is not yet feasible to standardize a technique for general use. Furthermore, the value of these tests for general use in evaluating welds has not been definitely established. The committee considered it advisable therefore not to include them as recognized, standard tests. On the other hand, the shear test which has been added, has been found to be a very practical, simple test for welds.

A. M. Candy,
J. A. Capp,
A. V. de Forrest,
W. B. Miller,
H. L. Whittemore,
F. M. Farmer (Chairman).

June 24, 1931.

Standard Tests for Welds*

FOREWORD

The primary purpose of this bulletin is to provide standardized procedures for the various mechanical tests which are made in connection with welds (tests of base metal, weld metal and sample welds, etc.) so that results of such tests will be comparable and any values properly deducible therefrom will be as reliable as possible. Only those tests and measurements have been included which the committee considers of most value in the evaluation of welds.

Tests of welds may be made for any one of several purposes—qualification of operators, comparison of filler metal (electrodes, welding rods and thermit mixtures), comparison of welding processes and similar purposes, design data, etc. Standards for tests of sample welds as *welds* should be distinguished from tests of sample welded joints (i.e., structural joints) as *joints*. In the former, a standard sample weld and standard test specimen therefrom can be prescribed but in the latter this is obviously not feasible because the design of the joint determines how a suitable test joint shall be prepared. The standards herein have

*Revision of Bulletin No. 1, American Bureau of Welding.

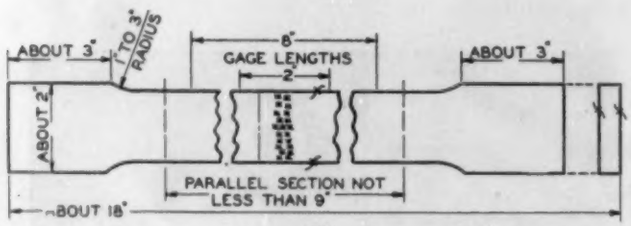
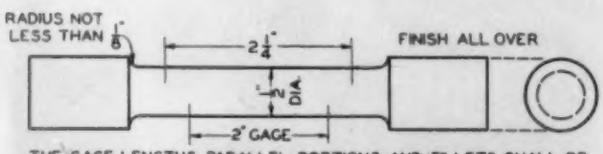


FIG 1



THE GAGE LENGTHS, PARALLEL PORTIONS AND FILLETS SHALL BE AS SHOWN, BUT THE ENDS MAY BE OF ANY FORM WHICH WILL FIT THE HOLDERS OF THE TESTING MACHINE

FIG. 2

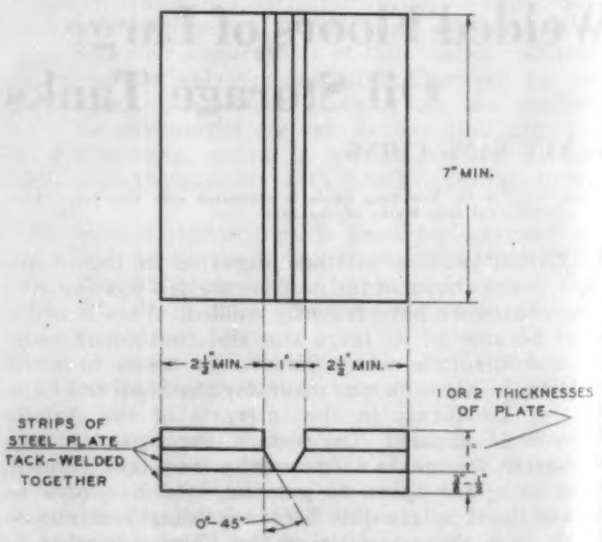


Fig. 3

been prepared primarily for tests of sample welds, but it is recommended that in the testing of sample joints, the procedures prescribed be used insofar as it is practicable to do so in order that all test results in connection with welds will be as comparable as feasible.

Satisfactory tests for welds in structures have not yet been developed. Such tests must necessarily be non-destructive, and while much attention is being given to this need of the industry and some progress is being made, the problem is a difficult one and the final solution for general use is not yet in sight.

It is recognized that for many purposes, a simpler procedure in a given test than that prescribed herein may be quite sufficient. It is recommended that in such cases the desired simplification be obtained by omission of observations and calculations that are not desired, but that those that are made be carried out in accordance with the procedure prescribed.

Preparation of Samples and Test Specimens

It is recommended that sample welds (for determining the proficiency of operators, comparing filler metal, etc.) be prepared from base metal in plate form and, if the edges are to be beveled (as is usually done with material over ¼ in. thick), that a single V butt joint, 30 or 45-deg. bevels be used (total angle 60 deg. or 90 deg.).

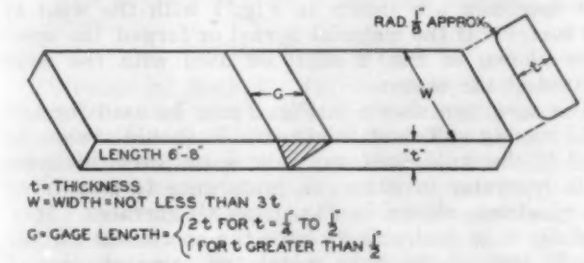


FIG. 4

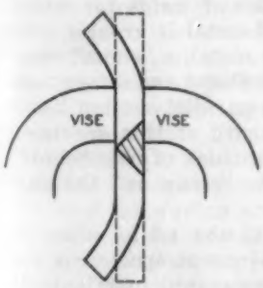


FIG. 5

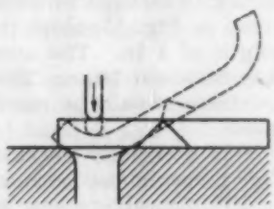


FIG. 6

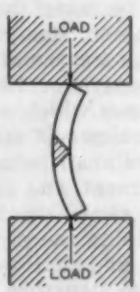


FIG. 7

FIG. 8

It is obviously not practicable to prescribe standard dimensions of the sample weld as these will depend upon the purpose of the tests and the number of tests to be made. Each sample weld should be of sufficient size to permit the preparation therefrom of all the test specimens prescribed herein for each of the different kinds of tests to be made. The sample weld should preferably be so made that the longest axes of the test specimens cut from it are parallel to the direction of rolling.

General Instructions

Wherever applicable, the standard procedure of the American Society for Testing Materials as given in "Tentative Methods of Tension Testing of Metallic Materials" (E8-27T) shall be followed.

Three duplicate specimens shall be tested in any one test and the average taken as the value of the property determined by that test.

Tensile Test, Base Metal

Test Specimen. The shape and dimensions of the test specimen for sheet or plate base metal are shown in Fig. 1. It is to be noted that a thickness in excess of ¾ in. will require a testing machine of 100,000-lb. capacity in the case of ordinary steel. If the spec-

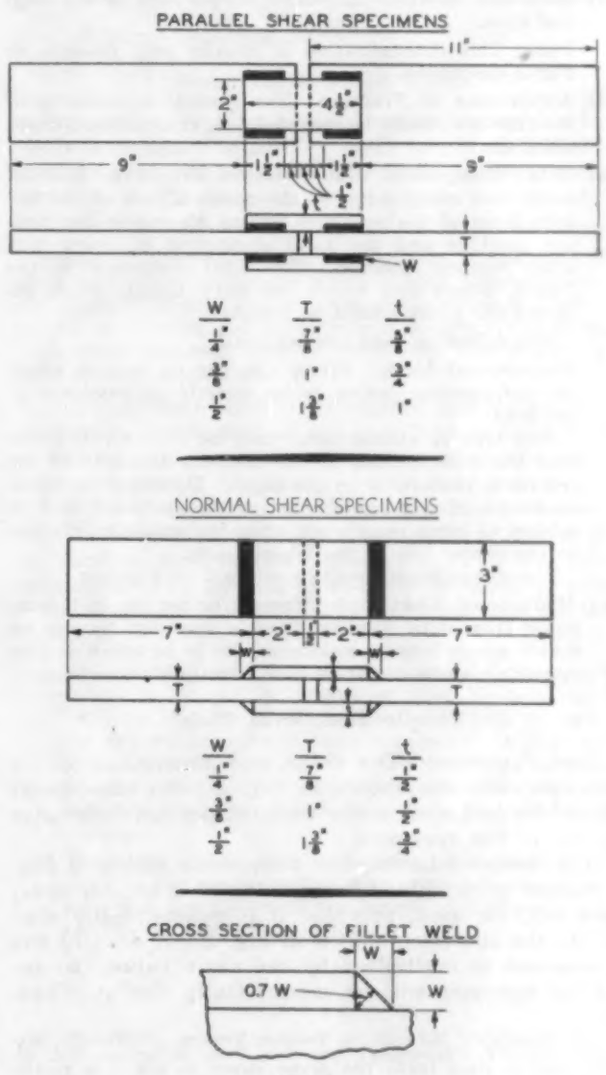


Fig. 9

imen is cut from regular commercial sheet or plate material, it is usually not necessary to machine the 1.5-in. faces of the specimen.

The shape and dimensions of the test specimen for either forged or cast base metal are shown in Fig. 2. It is advisable to make the radius of the fillets greater than the minimum (⅛ in.), say ¼ or ⅜ in. If the minimum radius is used a brittle specimen may fracture in the fillets.

Swivel specimen holders should be used to insure, insofar as possible, axial loading.*

As the properties of the material depend somewhat upon the shape of the specimen, it is advisable to use the same shape and size of specimen for the base metal that is used for the weld metal and for the welds.

Results to be Recorded. The following data are to be recorded in connection with tension tests of base metal:

(a) Ultimate Strength. Stress (lb. per sq. in.) computed from the area of the original section.

(b) Yield Point. Stress (lb. per sq. in.) at which marked increase in deformation of the specimen occurs without increase of load as indicated by a sudden dropping of the beam of the testing machine or by a sudden increase of the rate of elongation as shown by dividers.

(c) Reduction of Area. Expressed in per cent of the original area.

Note: This determination is usually only feasible on Fig. 2 specimens.

(d) Appearance of Fracture. The general appearance of the fracture should be recorded, i. e., crystalline, fibrous, silky, etc.

(e) Total Elongation. Gauge marks should be laid off every inch along a line at the center of one of the 1.5-inch faces of the specimen before placing in the testing machine and the total elongation in every inch after rupture recorded. The total elongation in the 1-inch, 2-inch and 8-inch (if any) length which included the break should be reported.

The following data are optional:

(f) Proportional Limit. Stress (lb. per sq. in.) at which the deformation ceases to be directly proportional to the load.

Any type of extensometer may be used which measures the deformations of two opposite elements of the specimen, preferably on the edges. Deformation measurements on only one element of the specimen may be subject to large error even when the gauge marks are on the center line of the 1.5-inch side.

The gauge length may be either 2 or 8 inches.

(g) Modulus of Elasticity. Stress (lb. per sq. in.) computed from data obtained from a specimen having an 8-inch gauge length; measurements to be taken on two opposite elements; one on each edge of the specimen.

Tensile Test, Weld Metal

Test Specimen. The shape and dimensions of the test specimen are shown in Fig. 2. No base metal should be included in the reduced portion (diameter ½ in.) of the specimen.

If a specimen having the dimensions shown in Fig. 2, cannot be machined from the weld a smaller specimen may be used, provided it is geometrically similar to the specimen shown in Fig. 2. If each of the dimensions is multiplied by the same value, the resulting specimen will be geometrically similar. Thus, if the value selected is ½, the diameter will be ¼ in., the gage length 1 in., the length of the reduced portion 1⅛ in., and the radius of the fillets, not less than 1/16 in.

If the specimen cannot be obtained from a weld it may be prepared from a bar of weld metal, 1 in. by 1 in. This bar shall be formed entirely by depositing filling metal in an open trough formed by tack welding together strips of standard steel plate, as shown in Fig. 3, employing exactly the same method used in making the corresponding test weld. After being deposited, much of the steel plate material can be cut away with a gas torch, leaving a rough rod from which the prescribed test specimen can be machined. Care should be taken, however, that the gas cutting is sufficiently distant from the weld metal to avoid any heat treatment effect on the latter.

In the case of thermit welding suitable refractory material should be used for the box instead of steel.

Results to be Recorded. The data to be recorded in connection with tension tests of weld metal shall be the same as for base metal except those involving an 8-in. length. If, however, the modulus of elasticity is desired, a specimen similar to that shown in Fig. 2 with a gage length of 8 in. shall be employed.

Tensile Test, Welds

Test Specimen. The shape and dimensions of the test specimen are shown in Fig. 1 with the weld at the center. If the material is cast or forged, the specimen shown in Fig. 2 shall be used with the weld located at the center.

The specimen shown in Fig. 2 may be used for any weld having sufficient thickness. It should always be used if the weld does not have a uniform thickness or is irregular in shape, in preference to machining the specimen, shown in Fig. 1, on all surfaces. Incidentally it is desirable to have the specimens for the tensile test of the base metal the same shape and dimensions as the specimens for the tensile test of the weld.

For determining the properties of welds for which the tensile strength of the weld metal is greater than the tensile strength of the base metal, a "short" specimen may be used which has the shape and dimensions given in Fig. 1, except that the parallel section has a length of 1 in. The overall length of this specimen may be about 10 in. The 1.5-in. sides of this "short" specimen should be machined to "clean up" the surfaces.

It is especially necessary that the 1.5-in. sides of Fig. 1 specimens be machined (except specimens for qualifying welders—see next paragraph), particularly if the two pieces of base metal are offset or if they form an angle at the weld. Tests made in the latter case, where the specimens are not machined, are not reliable. Furthermore, care must be taken that specimens having the latter defects are not "straightened" before being machined because such treatment is likely to materially decrease the strength of the weld. A roughing cut in a planer or shaper which will just "clean up" the surfaces of the specimen is sufficient.

Specimens for qualifying welders shall be straight, shall have a minimum of reinforcement, and shall not be machined only to the extent of removing the reinforcement. Specimens for determining the properties of a welded joint shall be straight, and shall be duplicates of the joints to be used in the structure.

Results to be Recorded. The following data are to

*See Tentative Methods of Tension Testing of Metallic Materials, E8-27T, Proceedings Am. Soc. Test. Materials, Vol. 27, 1927, Part I, page 1067—The device shown in Fig. 8 is recommended.

be recorded in connection with tension tests of weld specimens:

(a) Ultimate Strength. Stress (lb. per sq. in.) computed from the area of the original section.

(b) Appearance of Fracture. The appearance of the fracture as determined with the aid of a low-power magnifying glass shall be recorded. The character described by the following nomenclature should be covered indicating as far as possible the per cent of the total area which is involved. For example, "10 per cent not welded" would signify that approximately 10 per cent of the total area of cross section at the fracture is exposed base metal—that is, not welded.

Spongy: Full of small cavities; the structure resembles that of a sponge; porous.

Slag inclusions: Foreign matter entrapped in the weld.

Gas pockets: Small or large cavities more or less isolated (i. e., not of a regular spongy structure).

Not welded: Exposure of any portion of the surface of the base metal indicating imperfect fusion between the base metal and the weld metal.

Laps: Imperfect fusion between adjacent portions or between successive layers of weld metal.

Note: No provision is made for elongation measurements of any kind. Such measurements with the usual gauge lengths are of little value because of the predominating influence of the base metal. Where such data are required special provision should be made to get elongation readings over as short a distance as possible at the weld so as to include a minimum of base metal.

Bend Tests, Welds

Principle of Method. The specimen is placed as a strut in a vise or compression machine and a compression load applied at the ends until failure occurs in the outside fibers of the bent specimen. The relative evaluation of the ability of the specimen to withstand bending is measured by the elongation of the outside fiber.

Preparation of Specimen. For quantitative results rectangular specimens with widths at least *three times* the thickness shall be used. The edges should be rounded off so that fracture does not take place at the edge. The outside surface shall be smooth and free from local defects. The length may vary with the thickness of the piece and is unimportant provided it is long enough to allow performing the bending operation. (See Fig. 4.)

Procedure. The bend in the specimen is started by holding the specimen in a vise about one-third from the end, producing an initial bend at this point with hammer blows (see Fig. 5) or the specimen may be set up on cross supports and the bend started by a ram at the third point (see Fig. 6).

The specimen with the initial bend at each end is placed as a strut in a vise or compression machine and pressure applied gradually (i.e., without shock) at the ends until failure occurs in the outside fibers of the bend specimen (see Fig. 7). The specimen has failed when a crack is observed in the convex surface of the specimen between the edges. Cracks in an edge of the specimen shall not be considered failure. The appearance of small defects in the convex surface shall not be considered failure if the greatest dimension does not exceed 1/16 in. Speed is not a factor if there is no shock. The continuity of closing and the speed may be varied without affecting the results within the limits of accuracy expected, i.e., ±5 per cent of the value of the fiber elongation.

Result to be Recorded. The performance of the specimen is evaluated by measurement of the outside fiber elongation. The most direct method of doing this is to place gage marks within the limits of the weld metal of the specimen before bending and measure the extension directly with a flexible scale graduated to one hundredths of an inch.

Experiments have shown that for consistent results the gage length should be at least 0.3 in. and not greater than 1 in. With material less than ¼ in. thick, the difficulties of measurement are so great that the committee is not yet prepared to make definite recommendations.

Any other method of measuring the fiber elongation may be used, provided it gives the same values as the direct method. For example, in some cases it may be objectionable to put gage marks on the specimen, in which instance the radius of the outside of the specimen may be measured and the per cent elongation calculated according to the formula; per cent elongation $= 100\frac{t}{2R}$, where t = thickness and R = radius to neutral plane (see Fig. 8).

Shear Tests, Fillet Welds

Preparation of Specimens. Test specimens for fillet welds to be tested in *parallel shear* and in *normal shear* shall be prepared as shown in Fig. 9. Dimensions are indicated for three sizes of specimens corresponding to three sizes of welds, viz., ¼ in., ⅜ in. and ½ in.

Notes: It is essential that the stresses in the main and cover bars never exceed the elastic limit. These specimens are designed on the basis of a maximum stress of 25,000 lb. per sq. in. in main and cover bars of ordinary bar stock.

Standard bar stock may be cut to size with a torch and used without machining.

The specimens shall be assembled and clamped in a manner to insure that all welds will be parallel to the center line of the specimen and to eliminate spaces between plates. The craters shall be filled up.

Testing Procedure. All specimens shall be tested in the "as-welded" condition. Care shall be taken that no bending stresses are introduced. This is preferably insured by the use of swivel test heads or grips.

Results to be Recorded. The following data are to be recorded:

(a) Load at first crack and maximum load. Corresponding values in lb. per in. length of weld by dividing the loads by the sum of the measured lengths of each of the two welds (normal shear specimens) or four welds (parallel shear specimens) which fail. The measured length of the welds shall include filled-in craters, depressions or other defects caused by the welding operation.

(b) The usual details such as location of failure with respect to the specimen and with respect to the weld itself, and description of the fractured surfaces as prescribed for the tension tests.

CONTINUED FROM OCTOBER, 1931, ISSUE JOURNAL OF THE A. W. S.

SECTION 3

QUALIFICATION TEST RESULTS

3-1 GENERAL

For reasons beyond the control of the Committee, the qualification of welders covered a much longer period of time than had been anticipated. Difficulties arose in arranging for inspectors, particularly at shops which were not adjacent to large cities where competent men for this work were most readily found. Not all of the welders qualified on the first test, making it necessary to ask for the preparation of additional coupons. Further, the pressure of contract work prevented many shops from giving prompt attention to their assignments. These several factors accounted for most of the inability to carry the work to an earlier completion.

A total of 61 welders participated, of whom 42 welded program specimens. The previous experience of these 42 welders, and the results of their qualification test are given in Appendix 10-2, pages 120-1. It will be noted that eight of these welders failed to qualify, and that if the rules of the Committee had been strictly enforced, they would not have been permitted to weld program specimens. It was deemed expedient, however, to include the specimens of the following welders:

Welder W-C —Qualification coupons were lost in transit to the laboratory and the shop objected to repeating the tests.

Welders BY-B, MY-A, HY-A—Program specimens had been welded and shipped due to a misinterpretation of instructions.

Welder X-A —This shop was the last to weld specimens. If program specimens had been held up pending completion of qualification tests, they would have been made too late for inclusion in this report.

Welder KZ-A—Both qualification and program specimens had been welded before the inspector's arrival. Only 5V. and 5F. coupons were welded.

Welders F-A and DZ-B —In each case, one coupon was slightly below the specified minimum strength.

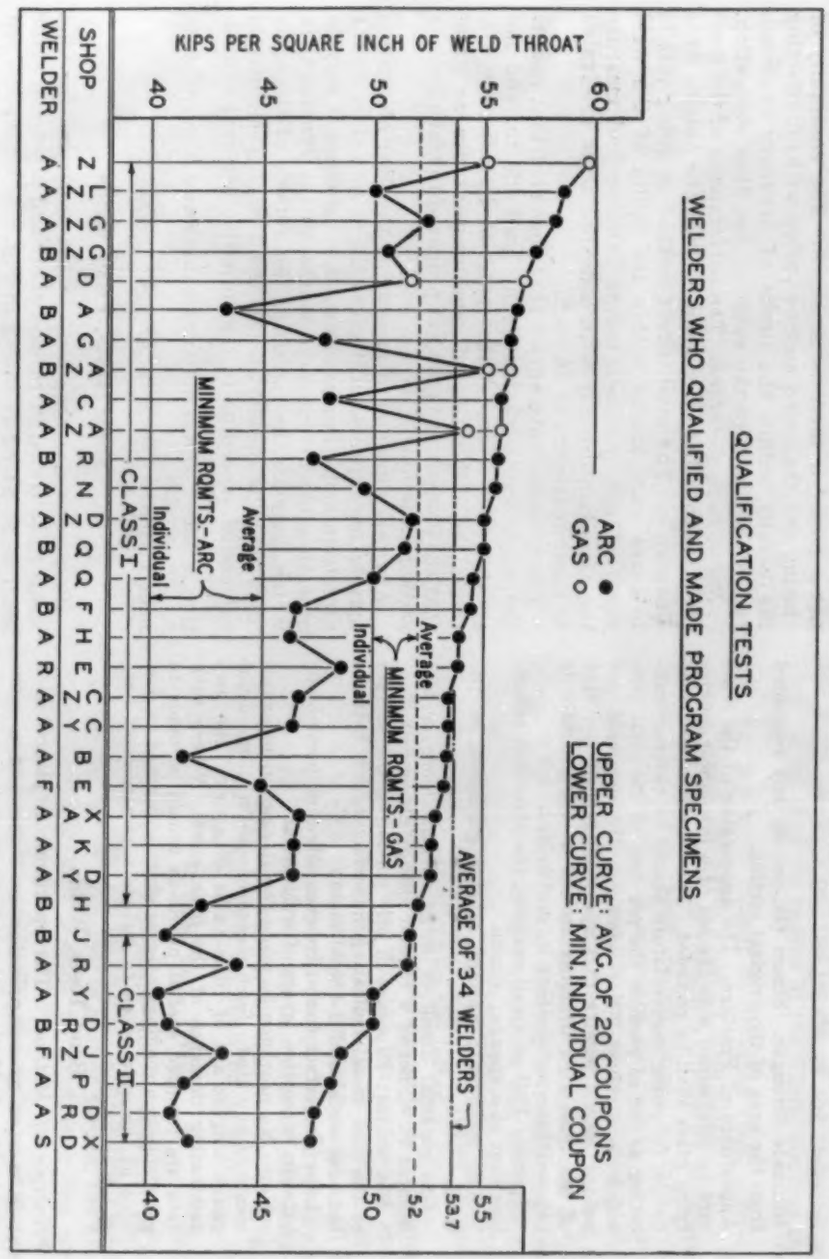

KIPS PER SQUARE INCH OF WELD THROAT
40
45
50
55
60
QUALIFICATION TESTS
WELDERS WHO QUALIFIED AND MADE PROGRAM SPECIMENS
ARC ●
GAS ○
UPPER CURVE: AVG. OF 20 COUPONS
LOWER CURVE: MIN. INDIVIDUAL COUPON
WELDER
SHOP
A A B A B A A B A A B A A B A A A R A A A F A A A B B A A B F A A S
Z L G G D A G A C A R N D Z Z Q Q F H E C C B E X K D H J R Y D J P D X
Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z Z
CLASS I
CLASS II
Individual
Average
MINIMUM RQMTS.-ARC
MINIMUM RQMTS.-GAS
AVERAGE OF 34 WELDERS
40
45
50
52
53.7
55

FIG. 13—Graph of Qualification Tests

Welders F-A and DZ-B —In each case, one coupon was slightly below the specified minimum strength.

FIG. 13—GRAPH OF QUALIFICATION TESTS

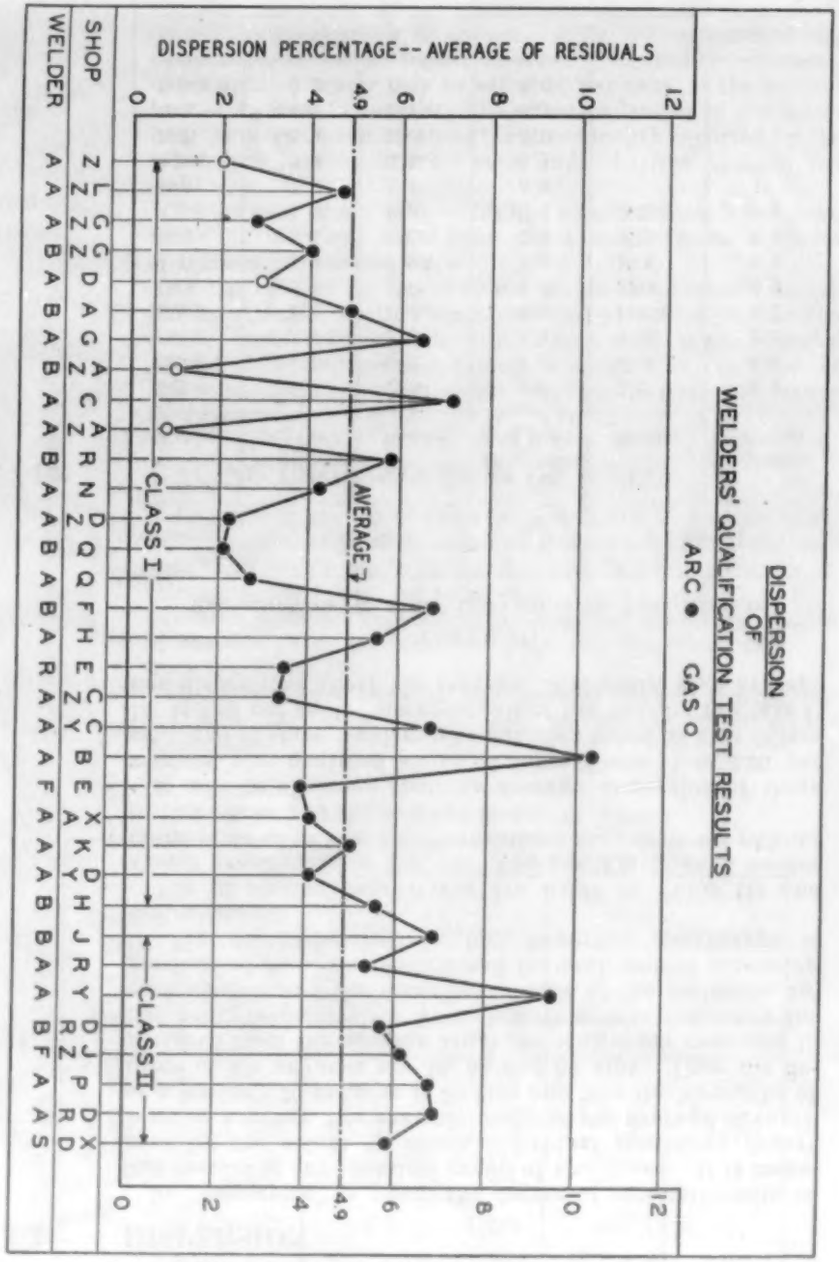

DISPERSION PERCENTAGE -- AVERAGE OF RESIDUALS
0
2
4
4.9
6
8
10
12
CLASS I
AVERAGE
CLASS II
DISPERSION OF WELDERS' QUALIFICATION TEST RESULTS
ARC ● GAS ○
SHOP
WELDER
Z L G D A C R N Q F H E Y B A K Y H J R Y J P R D
Z Z Z G Z A Z D Z C Z Q Z E C E X D D Y D J P X
A A B A B A B A A B A B A A A A F A A A B B A A B F A A S

FIG. 14—GRAPH OF WELDERS' DISPERSION

Data on the 19 welders who made no program specimens are given on page 122 of Appendix 10-2. Eleven failed to qualify, and although the Committee offered to permit the remaining eight to weld specimens, none were prepared by them. Shops CZ and DR used other welders who had qualified, Shops L, M, and FZ failed to weld their assignment, and the welder in Shop HZ left its employ before welding the specimens.

3-2 ANALYSIS OF RESULTS

3-2-1 WELDERS MAKING PROGRAM SPECIMENS

The results of the tests of 34 welders are shown graphically in Fig. 13. The average strength of each welder's 20 coupons is listed in order of descending strength. The value of his minimum strength coupon is also indicated. The weighted average of all the welders is 53.7 kips per sq. in., and the highest and lowest are 11.2 per cent above and 11.7 per cent below that value.

The flat coupons averaged 54.4 kips per sq. in., and the vertical coupons 52.8; a difference of 1.6 kips, or approximately 3 per cent.

In Section 6-1, Relation between Qualification and Program Tests, a classification of welders is made, based on the results of their qualification tests. For convenience and ease of cross-reference, the designations (Classes I and II) adopted in that Section are used in Table III and in Figs. 13 and 14.

3-2-2 WELDERS WHO MADE NO PROGRAM SPECIMENS

Qualification coupons made by these welders, all of whom used the arc process, showed strengths per sq. in. as follows:

Class of Welder	No. of Welders	Average of 12 Flat Coupons	Average of 8 Vert. Coupons	Average of 20 Coupons
Qualified	8	49.9	51.6	50.4
Not Qualified	11	45.2	45.9	45.5

3-2-3 GRAND AVERAGE RESULT

The average strength of the coupons of the 56 welders whose coupons were tested is 51.4 kips per sq. in. of weld throat.

3-3 DISPERSION

By "dispersion" is meant the degree of non-uniformity of test results in any identical group of specimens. It is measured by the extent to which individual specimens depart from an average. For example, suppose the average strength of a welder's 20 coupons is 50 kips and that the strengths of three of his coupons are 46, 52 and 56 kips. Then the departures from the average are 8 per cent, 4 per cent and 12 per cent, respectively. This departure was computed for each coupon and the mean percentage of the residuals, regardless of sign, was determined for each welder appearing in Fig. 13. Obviously, a low dispersion percentage is desirable.

The dispersion percentages are listed in Table III and shown graphically in Fig. 14. The position of each welder is the same as in Fig. 13. Percentages vary from 0.8 (AZ-A) to 10.4 (B-A) and the average is 4.9.

It will be observed that the average dispersion of those welders who qualified above 52 kips (Class I) is 4.35 per cent, and of those welders who qualified below 52 kips (Class II) is 6.68 per cent. Moreover, all of the welders in Class II had dispersions above the average. Evidently, high average

TABLE III

DISPERSION OF WELDERS' QUALIFICATION TEST RESULTS

CLASS I				CLASS II	
Welder	Dispersion Per Cent	Welder	Dispersion Per Cent	Welder	Dispersion Per Cent
Z-A	2.0	Q-B	2.1	J-B	6.9
LZ-A	4.7	Q-A	2.7	R-A	5.4
GZ-A	2.8	F-B	6.8	Y-A	9.5
GZ-B	4.0	H-A	5.6	DR-B	5.7
D-A	2.9	E-R	3.5	JZ-F	6.2
A-B	4.9	CZ-A	3.4	P-A	6.8
G-A	6.5	CY-A	6.8	DR-A	6.9
AZ-B	1.0	B-A	10.4	XD-S	5.9
C-A	7.2	E-F	3.9		
AZ-A	0.8	XA-A	4.1		
R-B	5.8	K-A	5.0		
N-A	4.2	DY-A	4.1		
DZ-A	2.2	H-B	5.6		
Average 4.35				Average 6.68	
Average 34 Welders—4.9					

strength for a group of welders is accompanied by low average dispersion.

3-4 LENGTH OF WELDER'S EXPERIENCE

It is interesting to compare the number of years of experience reported by welders with their test results. Considering the 34 welders whose results appear in Fig. 13, the average length of experience of the welders in Class I is 8 years; of those in Class II, 3¾ years.

SECTION 4

ADJUSTMENT OF LENGTH AND CROSS SECTION

Many previous tests have been made on specimens whose welds were machined so as to secure exactly the designed dimensions. Such tests are valuable from a laboratory standpoint and their interpretation is simple, for the reason that no allowance has to be made for tolerances in throat and length of welds. They would not, however, give the information desired by the Committee, i.e., what is the unit strength of welds made in commercial practice in which reasonable tolerances from the designed dimensions are permitted.

The Committee decided, therefore, that in its program specimens the welds should be left as made without machining. This decision placed on the Committee the added necessities of adopting a logical method for translating the actual test results in terms of the units of design, and of recommending a basis for measuring future welds made in commercial practice that will accord with the results thus translated.

4-1 EFFECTIVE LENGTH OF WELDS

What is meant by "effective length" is defined in the report of the American Welding Society Committee on Nomenclature, Definitions, and Symbols, under the term "weld length," as the length of the full cross-section of the weld, exclusive of the length of any craters. In the present Committee's specifications, a note on the title page of Section E reads: "The lengths of weld shown in the diagrams are net effective lengths. No weld shall start or end more than ¼ inch beyond the effective length."

Examination of the arc-welded specimens showed that fillet welds generally attain full section and fusion within ⅛ inch of the beginning of the weld, and end in a crater

Average 1.00	Average 0.98

Average 34 Welders—4.9

fillet welds generally attain full section and fusion within ⅛ inch of the beginning of the weld, and end in a crater

whose length is about ¼ inch. It is the opinion of the Committee, in line with general experience, that the efficiency of an unfilled crater may be set at 50 per cent, or the equivalent of ⅛ inch in length. The effective length of arc fillets has, therefore, been taken as the gross length reported by the laboratory less ⅛ inch at each end, i.e., less ¼ inch per weld.

In the case of arc butt welds the effective length has been taken as identical with their gross length since in these specimens the craters were filled.

In the case of all forms of gas welds the effective length has been taken as identical with the gross length for the reason that, preliminary to depositing a weld, the base metal is heated so that perfect fusion is secured at the start of the weld, and at the end of the weld the gas process leaves no crater.

4-2 GAGING CROSS-SECTION OF WELD

As regards gaging of cross-sectional size, it was the Committee's opinion that in order to make comparable the test results of welds made to the same design but differing in tolerance, they must be reduced to a common basis. This has been done by expressing their actual throat as a ratio of the designed, or minimum gage size specified, as illustrated in Table IV.

In cases where the size was greater than the maximum specified, the throat ratio was determined from actual dimensions.

TABLE IV

RATIO OF ACTUAL TO SPECIFIED FILLET THROAT

Specified Size = W Inches	ACTUAL WELD SIZE REPORTED				
	Minimum	Bar Thickness = W		Bar Thickness > W	
		Normal	Maximum	Normal	Maximum
	W	W	W	W + 1/16	W + 1/8
	W	W+1/16	W+1/8	W+1/16	W+1/8
¼	1.00	1.11	1.17	--	--
⅜	1.00	1.08	1.13	1.17	1.34
½	1.00	1.06	1.11	--	--
⅝	1.00	1.05	1.09	--	--
¾	1.00	1.04	1.08	--	--

SECTION 5

PROGRAM TEST RESULTS

5-1 DETERMINATION OF UNIT VALUES

The data reported by the shops and laboratories are given in Appendix 10-4. For fillet welds the throat of the weld has been reported as a ratio of the minimum, or designed size. For butt welds, the throat has been considered as equal to the bar thickness. Practically all butt welds had the minimum specified reinforcement, consequently no throat ratio has been reported for butt welds.

The method adopted for reporting the unit strength of butt welds is in accord with the provisions of the American Welding Society Code for Fusion Welding and Gas Cutting in Building Construction, which requires butt welds to be reinforced, but applies the permissible unit stress to the unreinforced throat size.

The unit values tabulated under the caption "Actual" are the test loads divided by the gross length reported by the laboratories, without any adjustment for throat ratio.

The values tabulated under the caption "Adjusted," are the test loads divided by the product of effective length and throat ratio, as explained in Sections 4-1 and 4-2.

For those specimens in which failure occurred in the bar, the strength of the weld has been assumed to be equal to the ultimate recorded load. Obviously, this assumption errs on the side of conservatism.

5-2 GRAPHICAL PRESENTATION OF RESULTS

The adjusted results of the program tests are shown in graphical form in Figs. 15 to 28, inclusive. In order to facilitate the comparison of related series, their arrangement in these graphs is not in numerical sequence. All values are given in kips per linear inch of weld. For fillet welds they are the values given under the caption "Adjusted"; for butt welds, those given under the caption "Actual."

Arc-welded specimens are shown by solid circles and gas-welded specimens by open circles. An "X" does not represent a specimen; it merely indicates that the specimen next to which it is placed, failed in the bar. The broken line shown on the graphs joins those points which indicate the average strength of each specimen group.

For the sake of clearness, the Series designation has been placed above the graph near the sketch it typifies, and only the last two digits of the specimen group are given on the horizontal, or abscissa scale. The first of these two digits, it will be remembered, represents the thickness of the b, or middle bar, in eighths of an inch; the second digit represents the weld dimension (the leg of a fillet weld or the throat of a butt weld), also in eighths of an inch. Thus, in the upper graph of Fig. 15, the complete numbers of the first five groups are 1022, 1033, 1044, 1055, 1066—in all of which both b bar and weld increase from ¼ in. to ¾ in. The next four are groups 1033, 1043, 1053,and 1063, in which the weld remains constant at ⅜ in., while the bars increase from ⅜ in. to ¾ in.

In Series 1000, 1300, 1900, 2100, and 2300, specimen groups 33 are duplicated on the graphs to facilitate comparison.

5-3 COMMENT BY SERIES

No comment is made on Series that displayed self-evident behavior.

SERIES 1000, FIG. 15

In this non-symmetrical form of joint, having fillet welds at the ends of only the b bar, only two specimens, both gas, failed in the bar, fracture taking place in the c bar at the edge of the weld. All other specimens, arc and gas, failed along the leg of the weld at the end of the b bar, as illustrated in Fig. 29. The photograph also indicates the extent of the bending that took place. Such distortion produces a prying effect* which may be resolved into tension combined with bending in the b bar leg, and shear combined with bending in the c bar leg. The total tension is, therefore, greater on the b bar leg, causing failure to occur in that plane.

The majority of specimens which lie below the average line contain local defects in the weld, principally insufficient penetration and only partial fusion at the root. The effect of such imperfections in a weld subjected to prying is proportionately greater than in a weld subjected to nearly pure shear, for the reason that in this type of specimen failure begins at the root and progresses outward.

The bars of specimens 1022-A and 1033-A were not in line, which probably accounts for their low strength.

(Comment by Series continued on page 62.)

*The flexure to which fillet welded joints may be subjected is of two kinds. In the kind which in these comments is termed "prying," the flexure is resisted mainly by the weld width, and in that case the distortion tends to pry open the weld. In the kind which is termed "bending," the flexure is resisted by a longer lever arm, such as the weld length (Series 2100) or the distance between a pair of welds (Series 1300), and in that case the distortion occurs mostly in the bars.

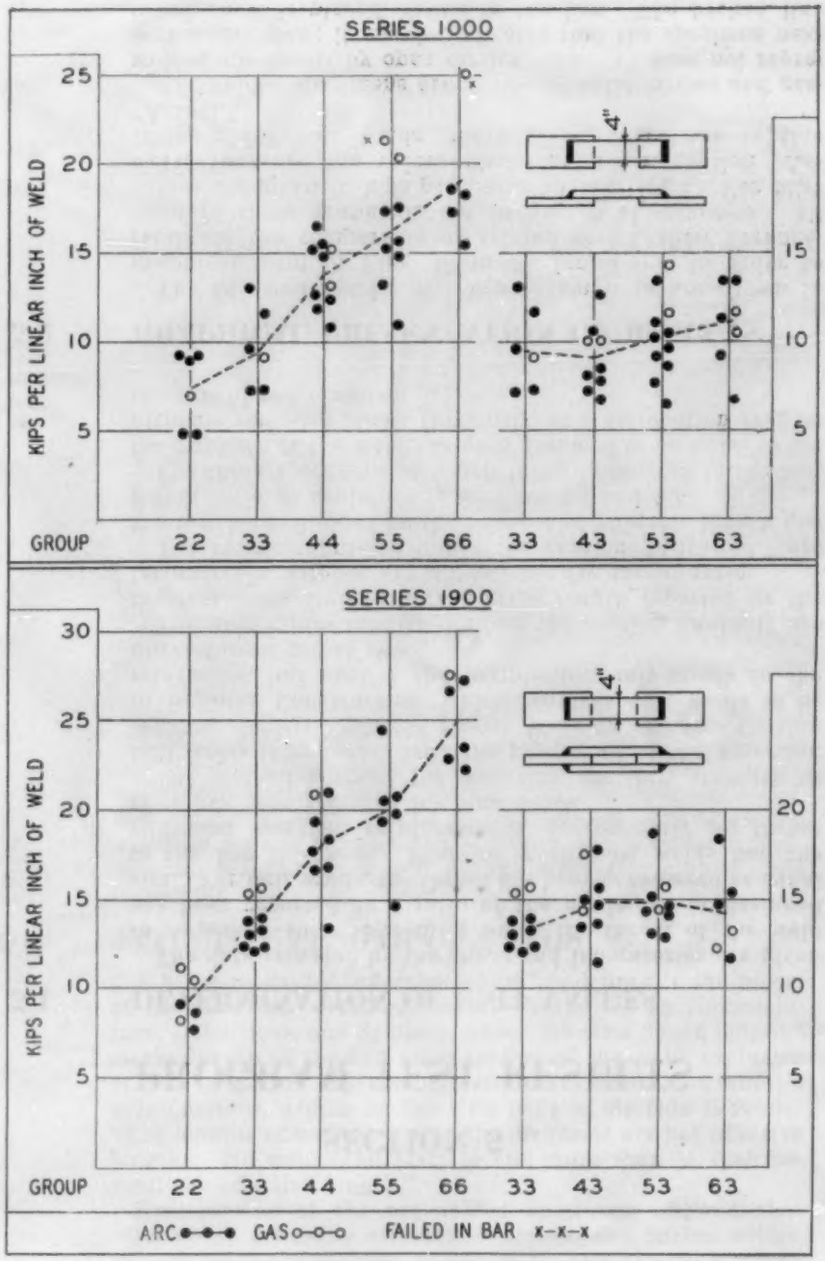


FIG. 15—GRAPH OF PROGRAM TESTS

flexure is resisted mainly by the weld width, and in that case the distortion tends to pry open the weld. In the kind which is termed "bending," the flexure is resisted by a longer lever arm, such as the weld length (Series 2100) or the distance between a pair of welds (Series 1300), and in that case the distortion occurs mostly in the bars.

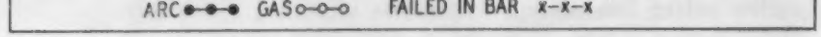


FIG. 15—GRAPH OF PROGRAM TESTS

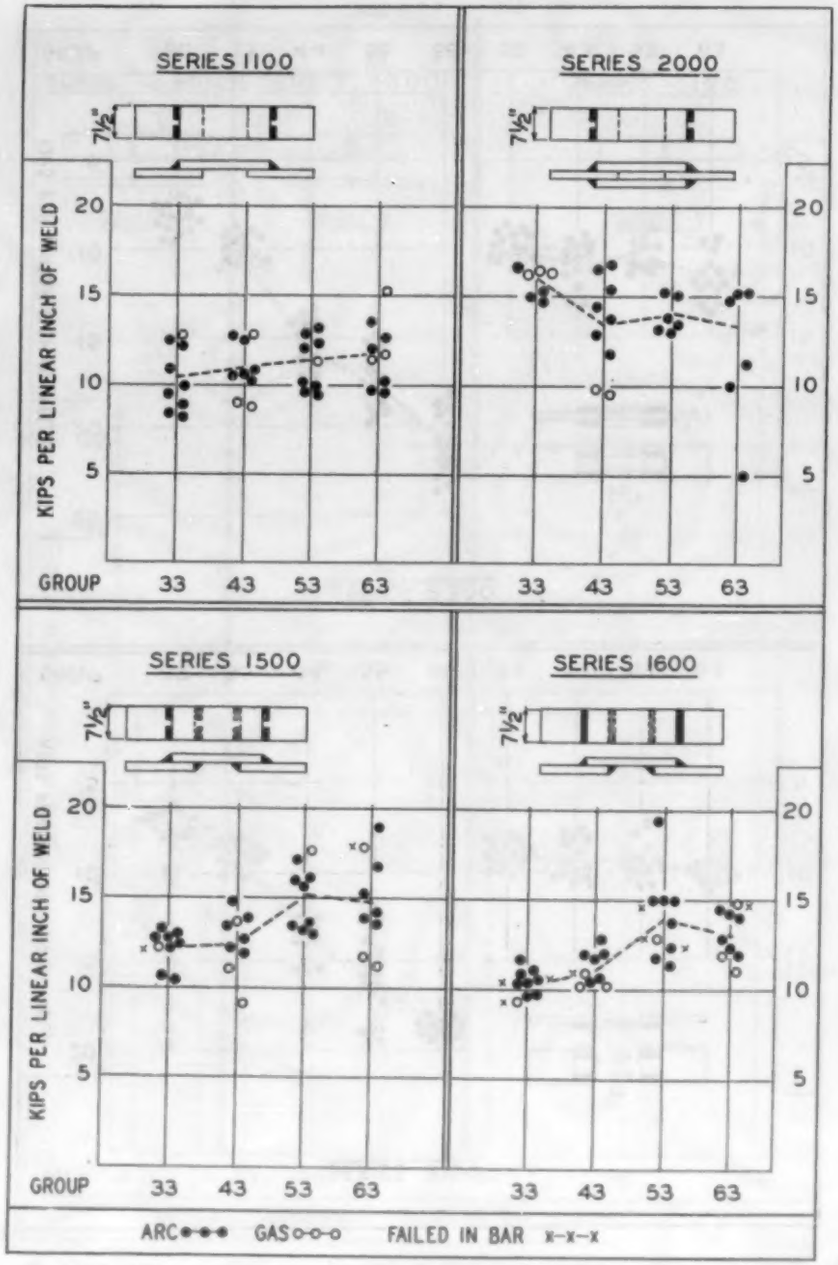


FIG. 16—GRAPH OF PROGRAM TESTS

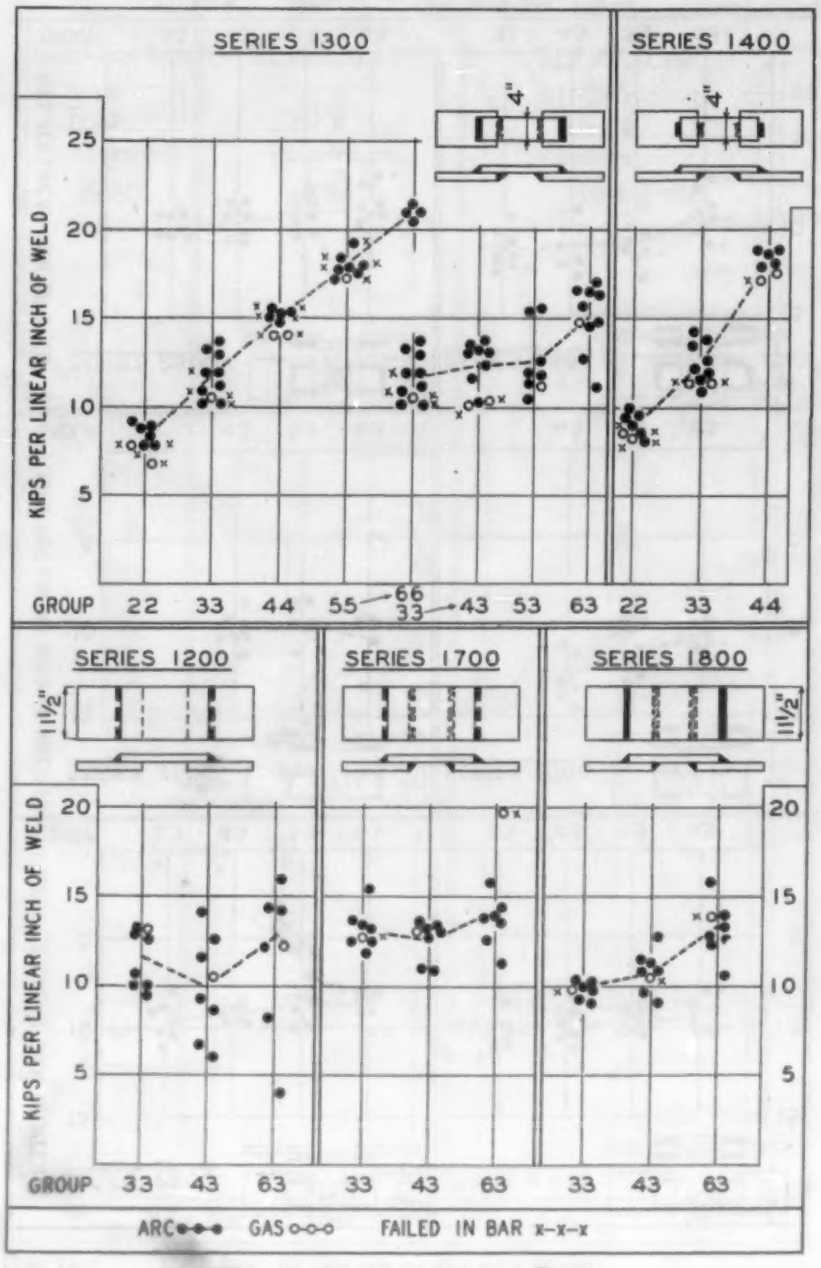


FIG. 17—GRAPH OF PROGRAM TESTS

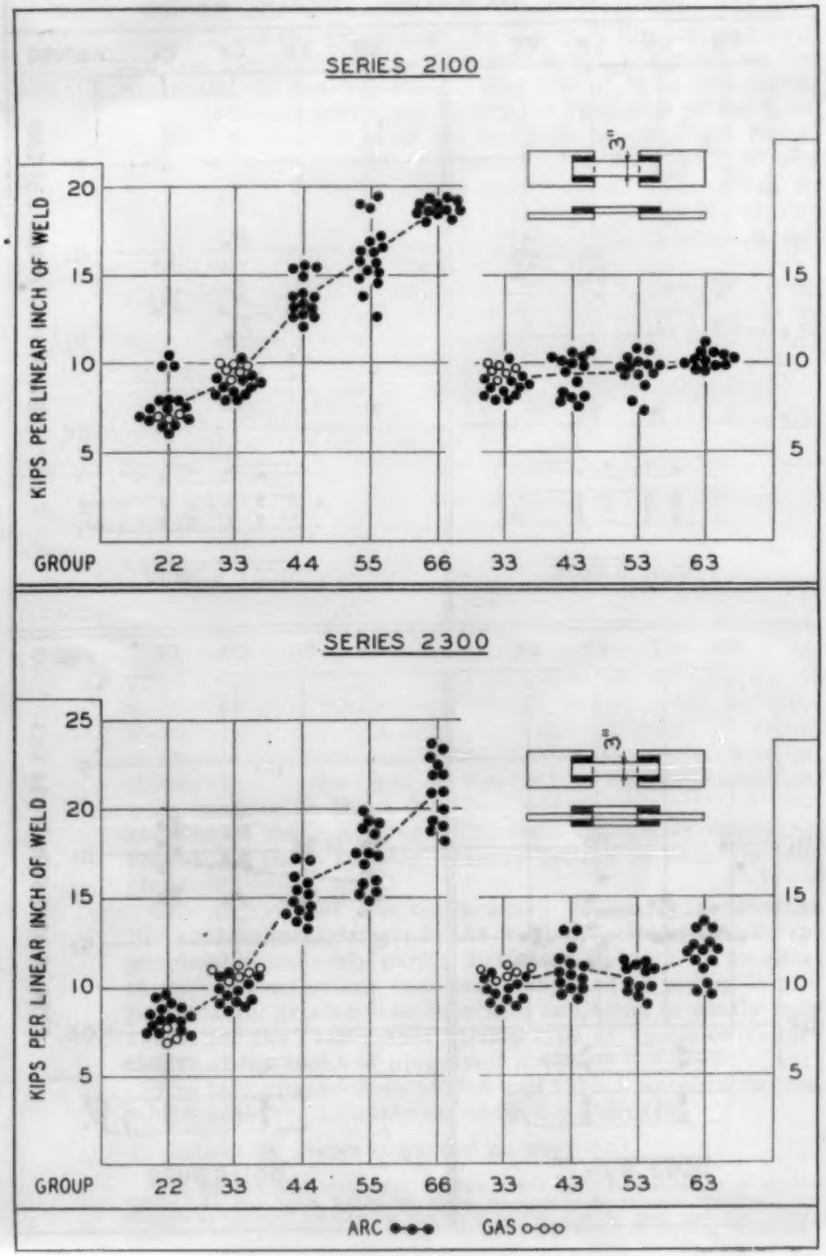


FIG. 18—Graph of Program Tests

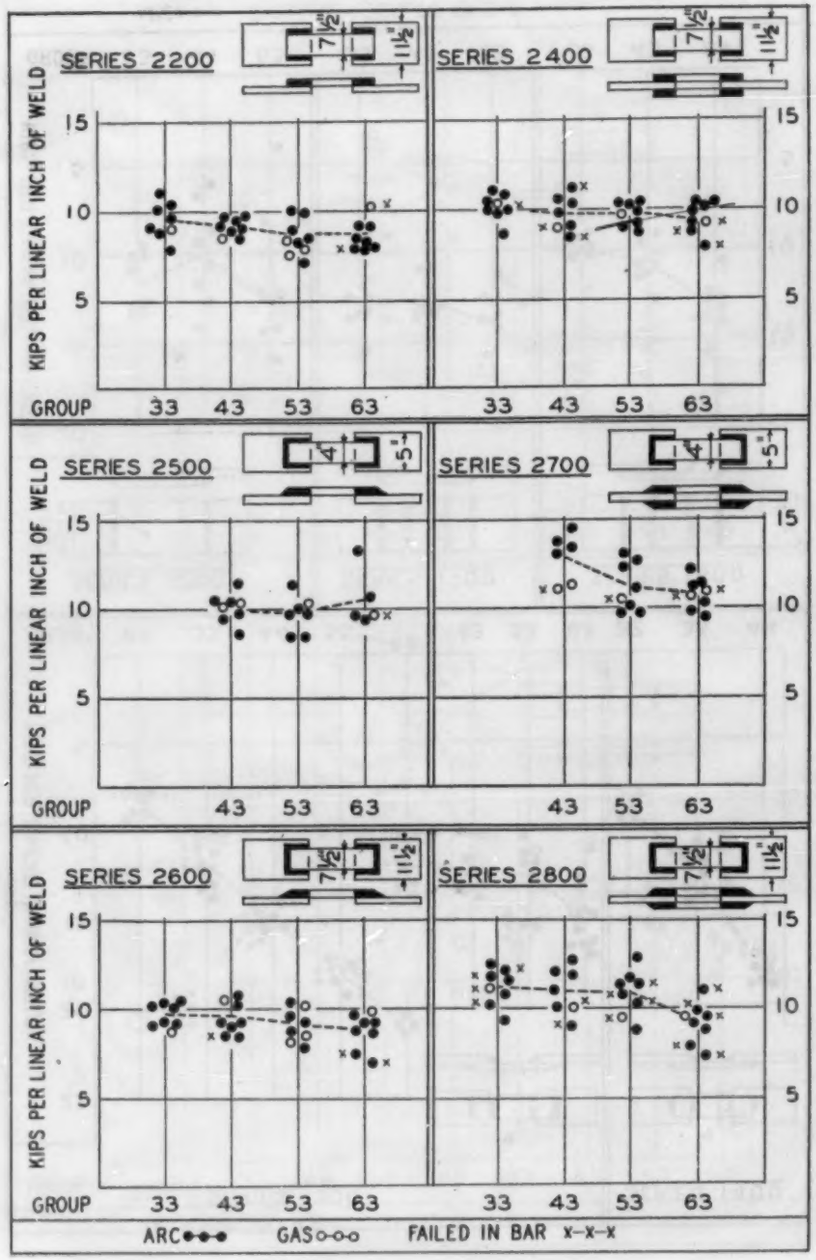


FIG. 19—Graph of Program Tests

FIG. 18—GRAPH OF PROGRAM TESTS

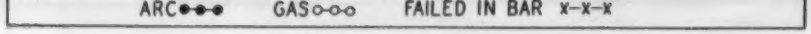


FIG. 19—GRAPH OF PROGRAM TESTS

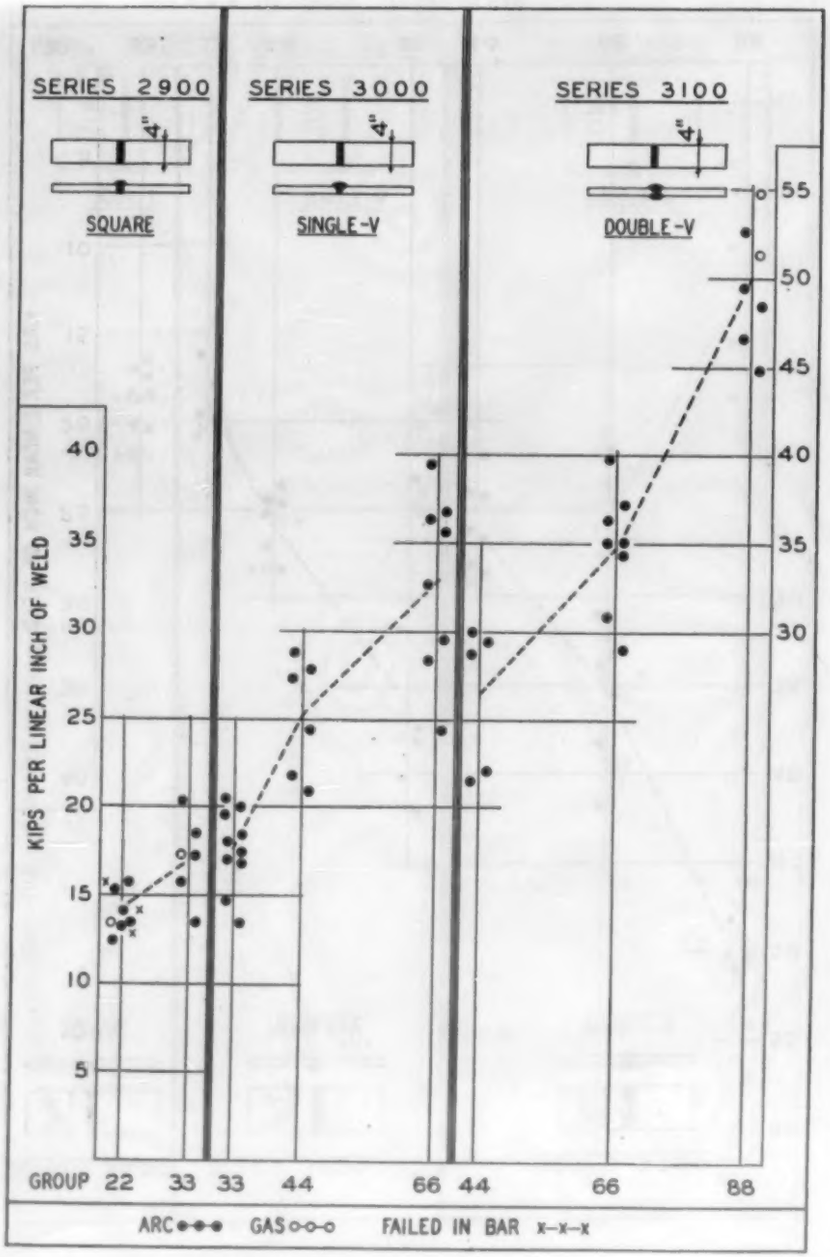


FIG. 20—GRAPH OF PROGRAM TESTS

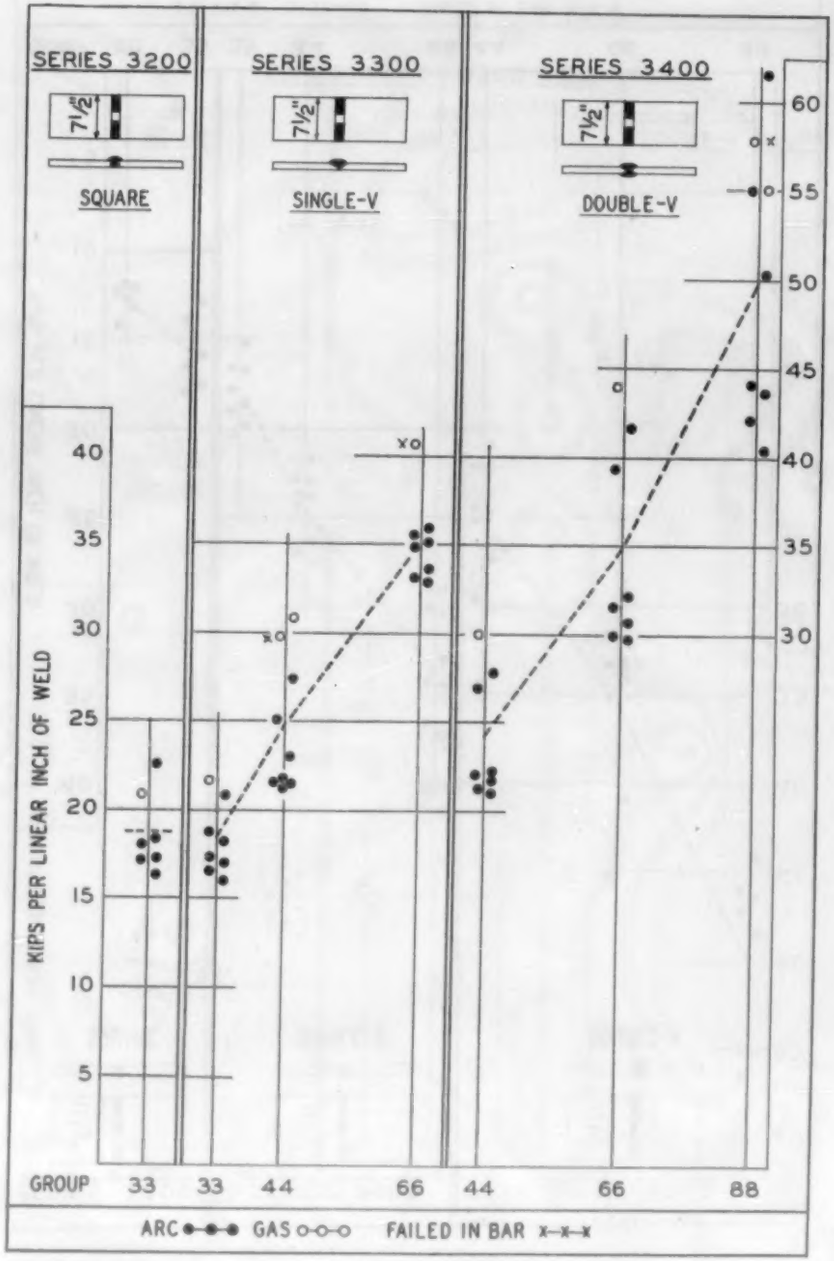


FIG. 21—GRAPH OF PROGRAM TESTS

Page Fifty-Four

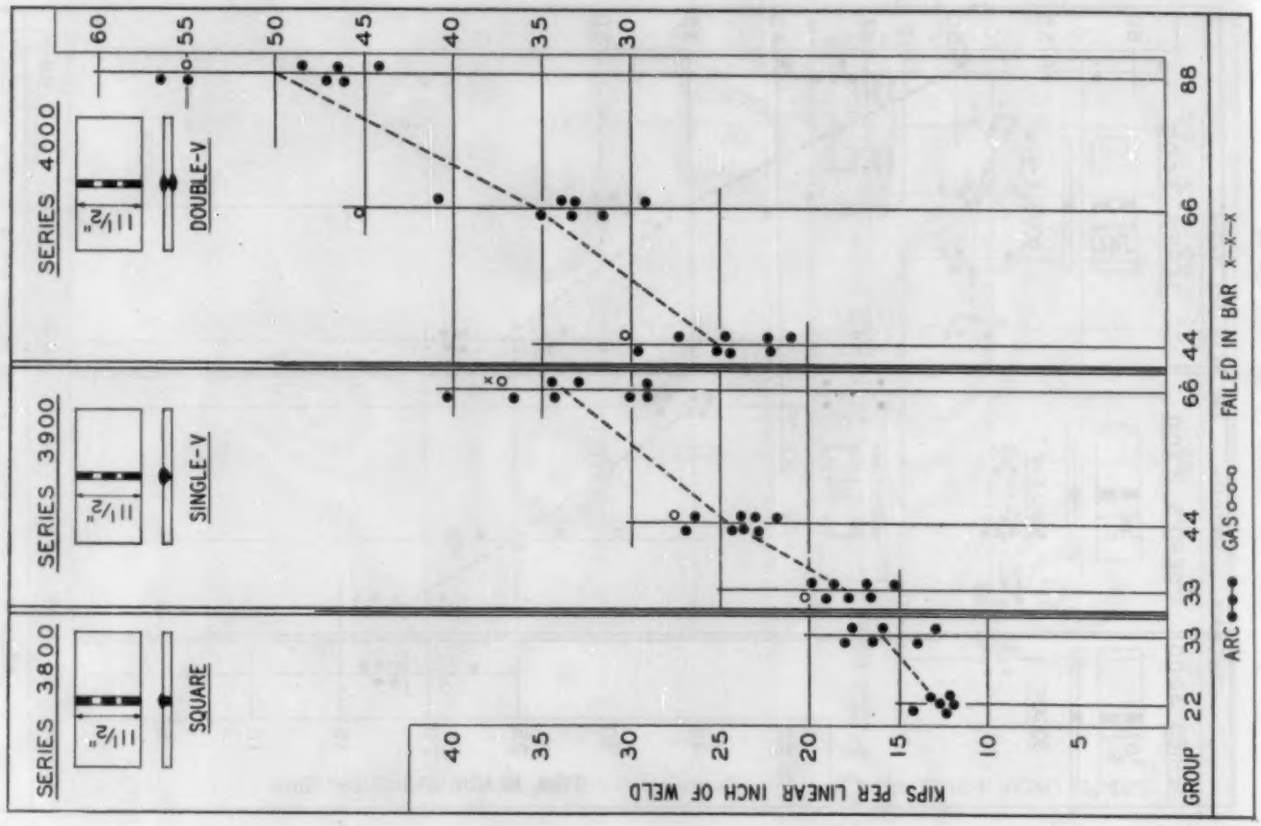


FIG. 23—GRAPH OF PROGRAM TESTS

Page Fifty-Three

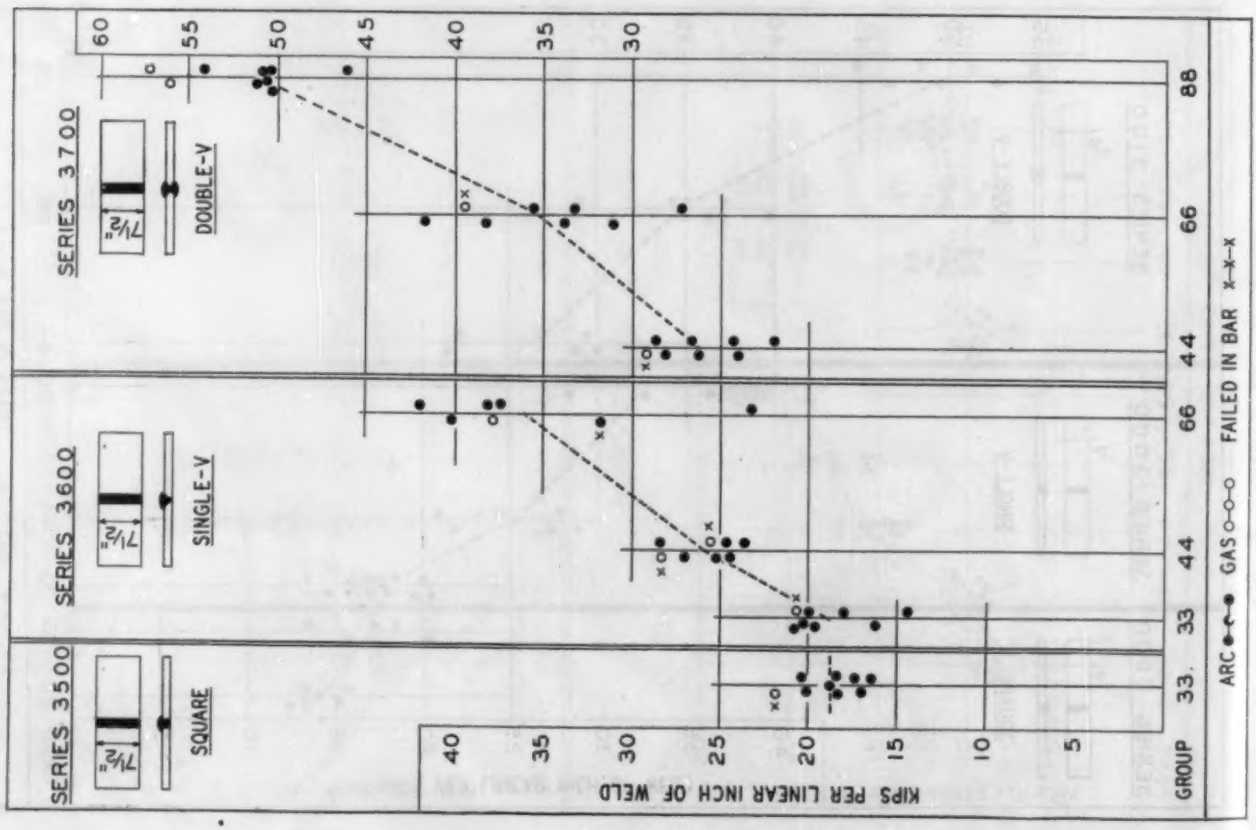


FIG. 22—GRAPH OF PROGRAM TESTS

FIG. 22—GRAPH OF PROGRAM TESTS

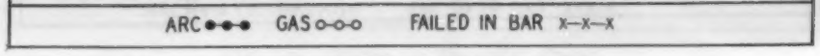


FIG. 23—GRAPH OF PROGRAM TESTS

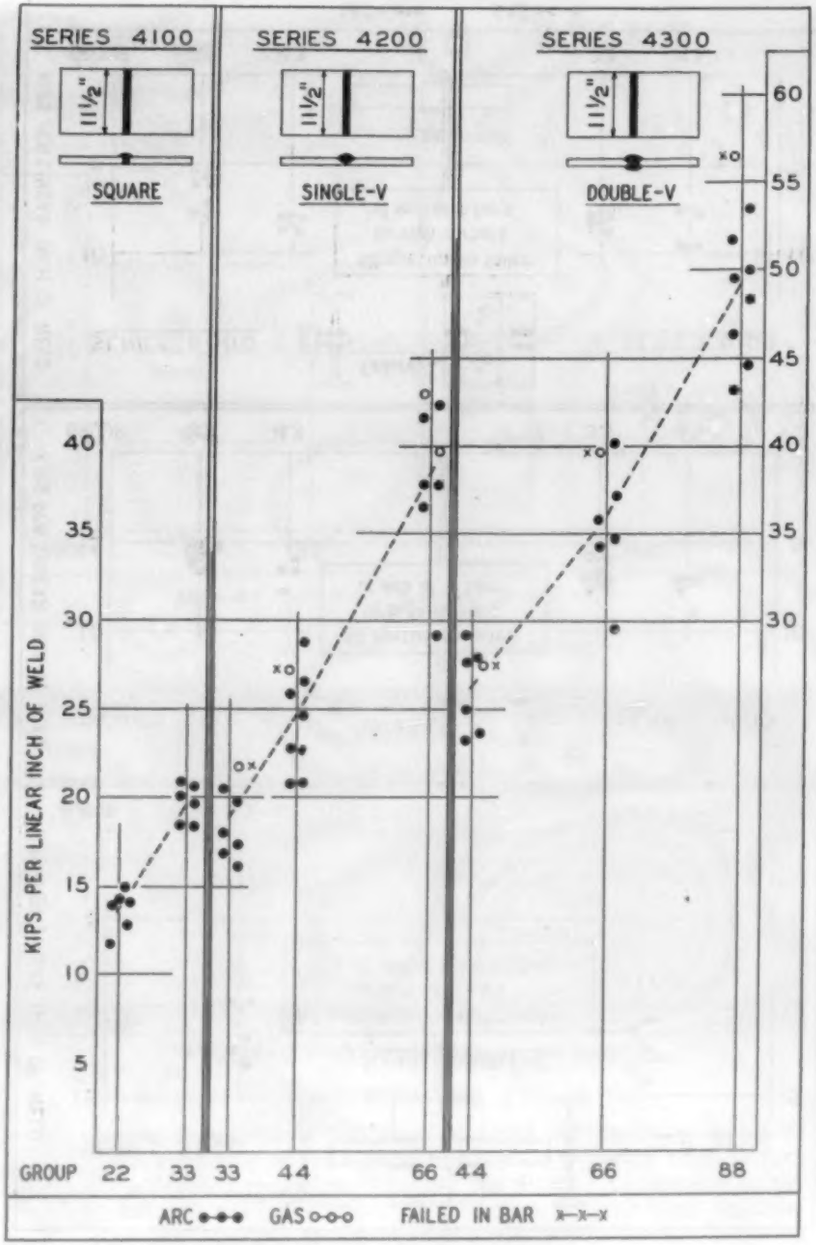


FIG. 24—GRAPH OF PROGRAM TESTS

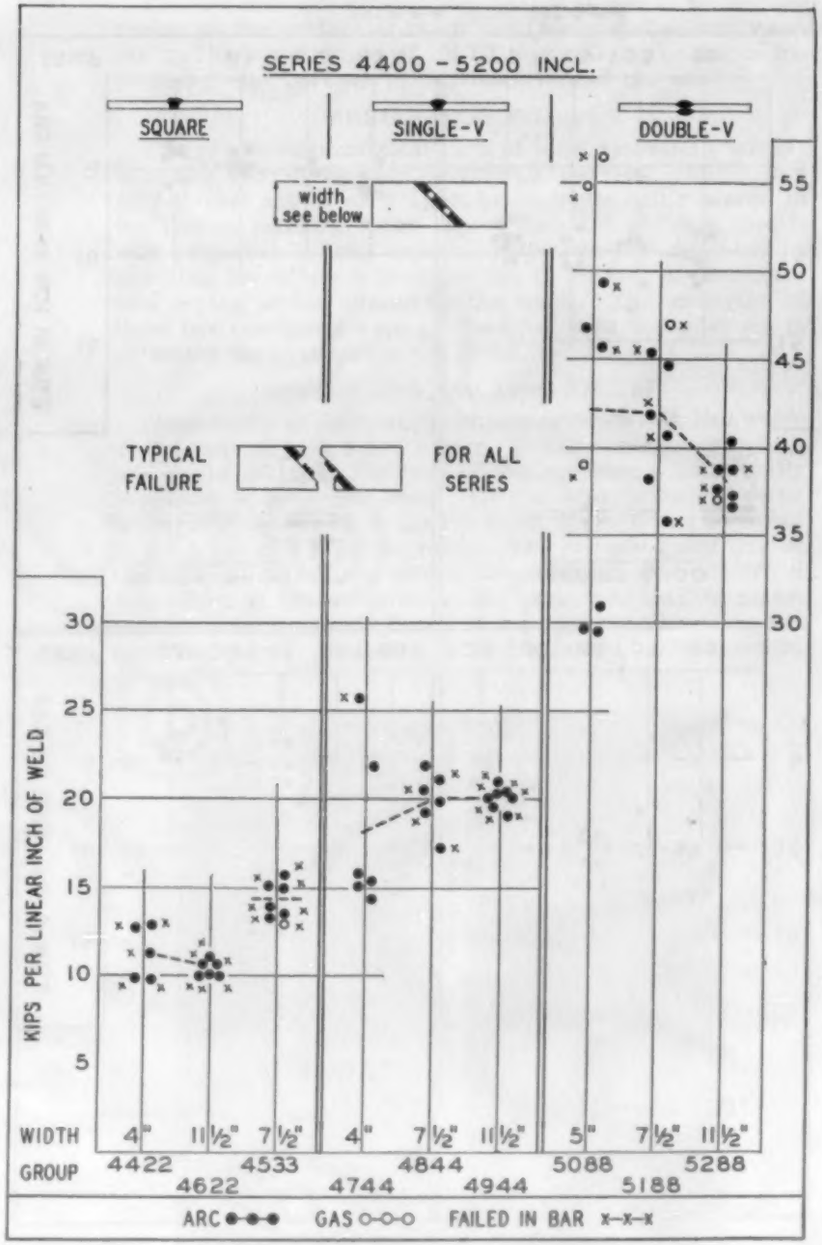

SERIES 4400 - 5200 INCL.
SQUARE
SINGLE-V
DOUBLE-V
width see below
TYPICAL FAILURE
FOR ALL SERIES
KIPS PER LINEAR INCH OF WELD
WIDTH 4" 11½" 7½" 4" 7½" 11½" 5" 7½" 11½"
GROUP 4422 4533 4622 4844 4744 4944 5088 5288 5188
ARC GAS FAILED IN BAR

FIG. 25—GRAPH OF PROGRAM TESTS

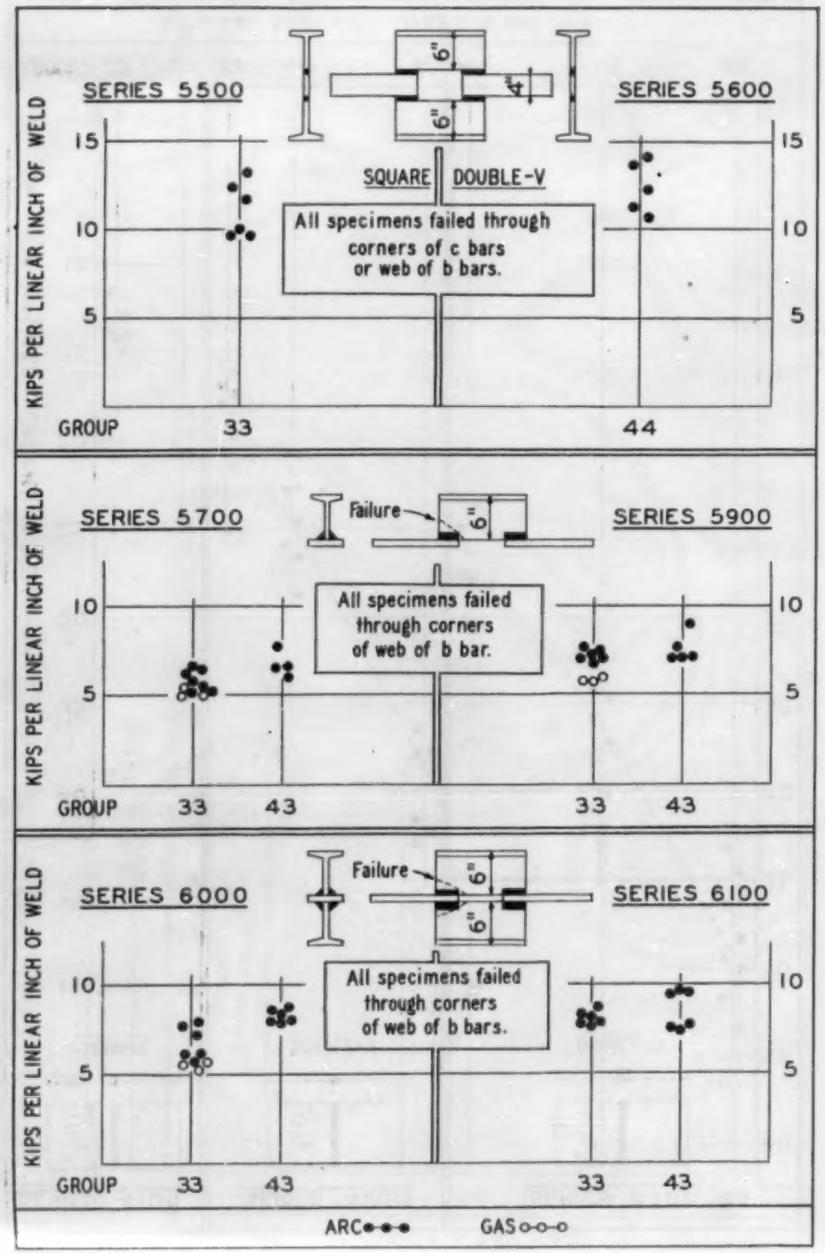


FIG. 26—Graph of Program Tests

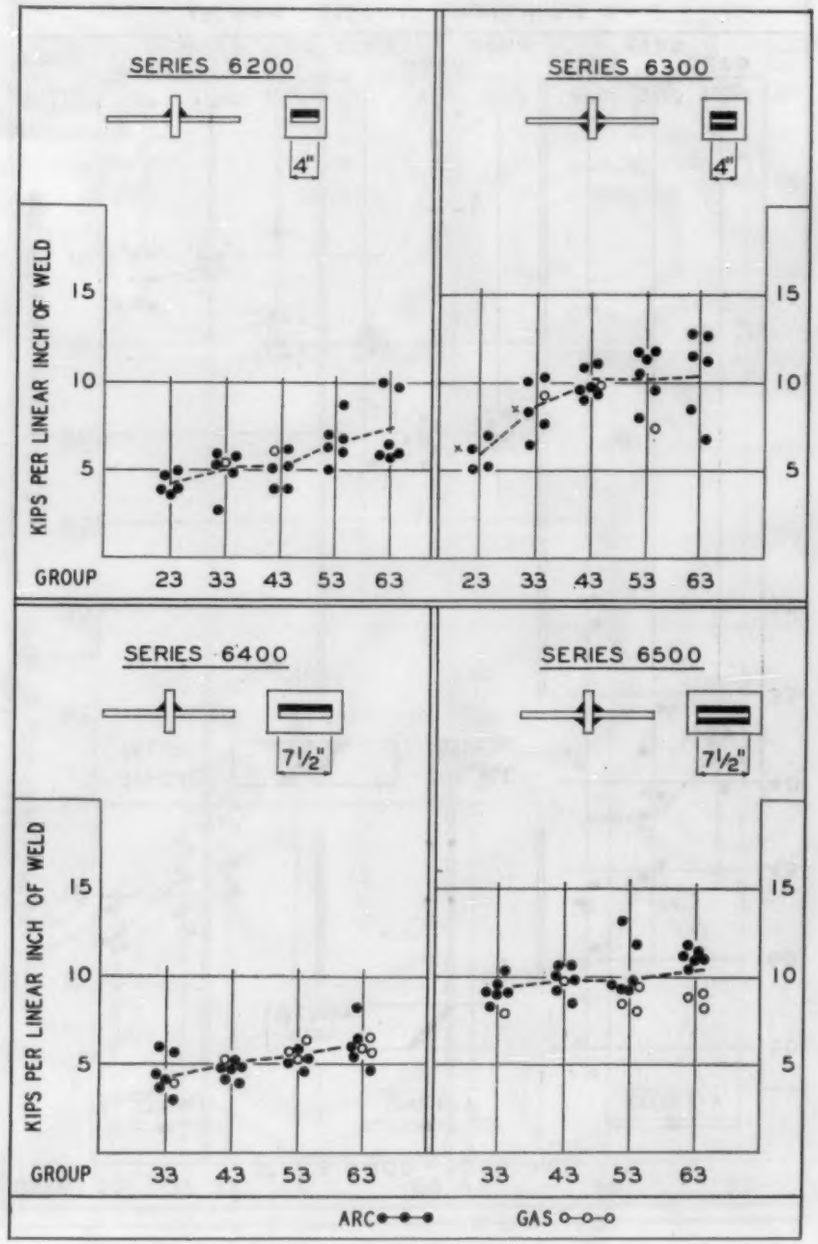


FIG. 27—Graph of Program Tests

FIG. 26—GRAPH OF PROGRAM TESTS

FIG. 27—GRAPH OF PROGRAM TESTS

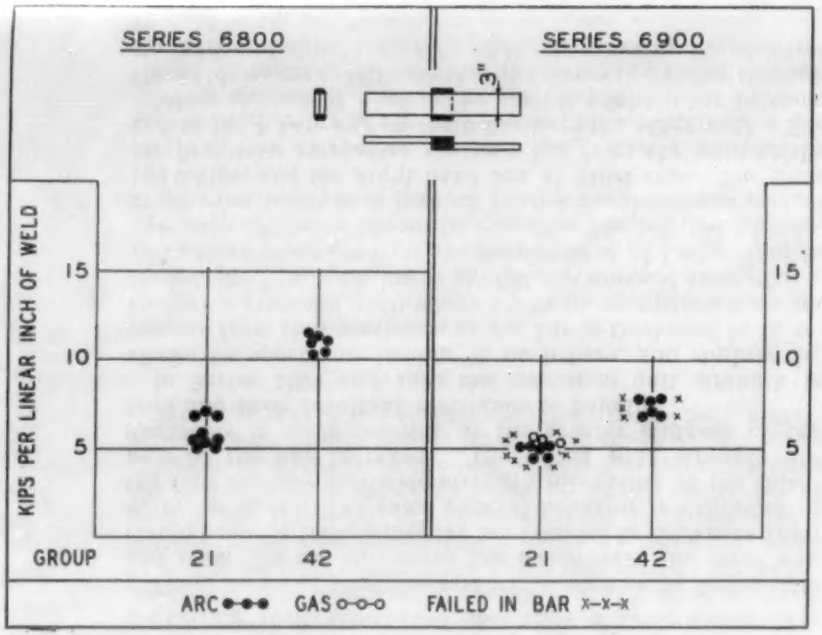


FIG. 28—GRAPH OF PROGRAM TESTS

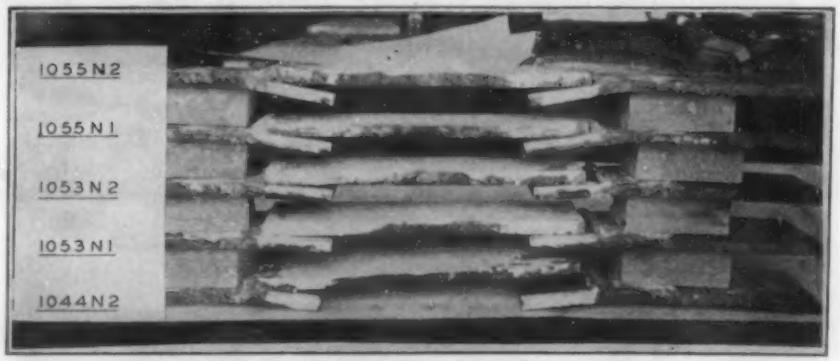


FIG. 29—TYPICAL FAILURES—SERIES 1000

SERIES 1900, FIG. 15

In this symmetrical form of joint, having fillet welds at the ends only of the b bars, in contrast to Series 1000, failure occurred through the throat of the fillets. The strengths per inch of weld are about 35 per cent greater than the corresponding specimen groups of Series 1000. Both phenomena in Series 1900 are due to the symmetrical form of specimen.

The low strength of specimen 1944-F is due to incomplete fusion on the surface of the c bar (horizontal during welding). The low strength of 1955-XA appears to be due to imperfect fusion between successive layers of the weld.

SERIES 1200, FIG. 17

This is a non-symmetrical form of joint, essentially similar to Series 1000. The bars of 1263-CZ were out of line, and 1263-B (not shown on graph), broke while being placed in the testing machine. The report does not indicate that it was subjected to any especial abuse during shipment or handling. Its failure is probably due to the lack of resistance to a prying action offered by the welds. The strengths of these two specimens were not included with the other six in obtaining the average for the group.

SERIES 1300 AND 1400, FIG. 17

These forms of joint, although non-symmetrical, had welds at the ends of both b and c bars. It was expected that failure would occur in the bars of the specimens, as actually happened in half the cases. Of the 54 specimens having welds with legs equal to the thickness of the b bar, 26 failed in the b bar and 28 in the welds. The increased strength of these Series over Series 1000 is due to the more symmetrical disposition of the welds about the horizontal loading plane, and the consequent confining of most of the flexure to the bars instead of producing a prying effect on the welds. (Fig. 30.)

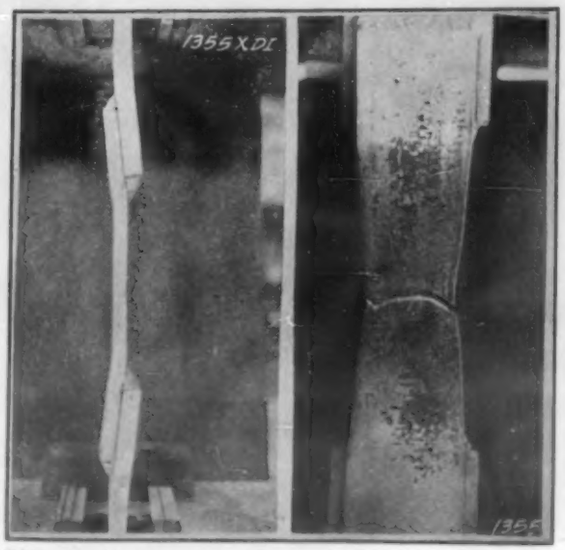


FIG. 30—BENDING AND FAILURE IN BAR—SERIES 1300

In these specimens in which the weld size remained 3/8 in. while the bars increased in thickness, failure was forced in the welds because of the additional strength and stiffness of the bars. In these cases the breaks at the end of the b bar were square, and at the ends of the c bars, in the throat of the welds. (Fig. 31.)

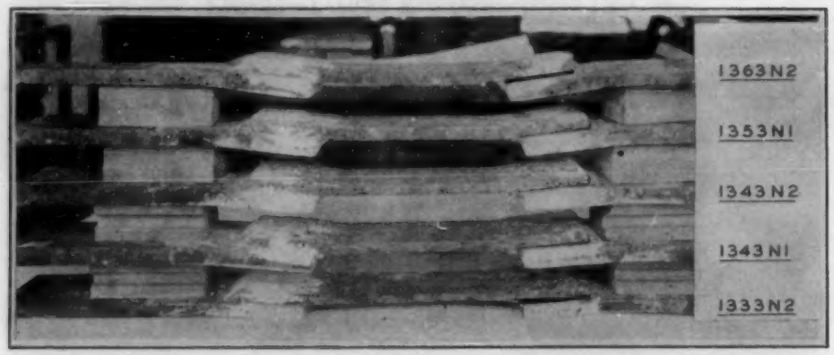


FIG. 31—TYPICAL FAILURE IN WELDS—SERIES 1300

SERIES 1500, 1600, 1700 AND 1800, FIGS. 16 AND 17

These forms of joint are essentially similar to Series 1300 and 1400. In the specimens the welds were the same size throughout, 3/8 inch, while the bars varied in thickness from 3/8 in. to 3/4 in. The same general behavior is exhibited in the four Series—unit weld strength increasing as the thickness of the bar increases. The added weld strength undoubtedly is made possible by the greater stiffness of the bars and their resultant resistance to bending.

In Series 1500 and 1600 the maximum unit strength is shown by specimens having 5/8 in. b bars, and slightly decreases from that maximum as the bar is thickened to 3/4 in. In Series 1700 and 1800 where no 5/8 in. specimens were included, the 3/4 in. specimens exhibit the greatest strength.

An interesting study of the development of Luder lines in Specimen 1833-A is shown in Fig. 32. The left hand photograph was taken at a load of 129.0 kips, the center one at 180.0 kips, and the right hand one at 246.0 kips. The lines are first seen emanating on the c bar from the weld at the end of the b bar, and on the b bar over the other weld. The relative absence of lines in the portion of the b bar between the welds seems to indicate that the stress is passing through the under (faying*) surface of the bar, taking the shortest path through the bars.

*Faying: The term "faying" is borrowed from shipbuilding parlance as a convenient term to denote the surfaces in contact.

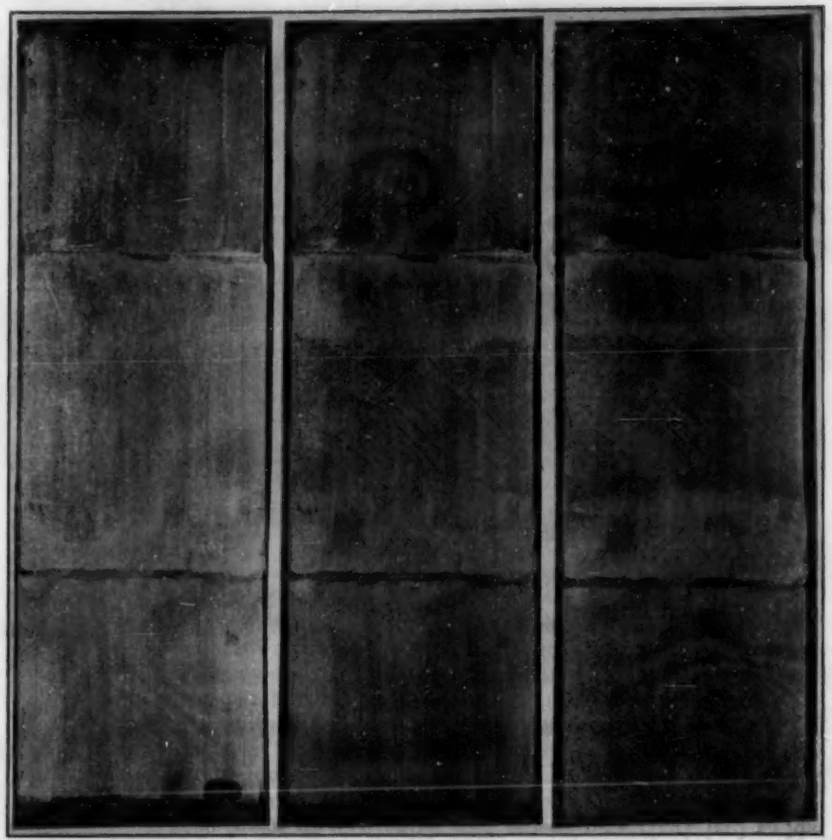


FIG. 32—STRAIN LINES ON END WELDED SPECIMEN 1833A

SERIES 2000, FIG. 16

The symmetrical form of specimen is here also accompanied by high strength. With regard to the low specimen 2063-B3, the welds were reported as undersized, averaging about 5/16 in. In answer to an inquiry, the laboratory replied, "Further inspection showed there was no fusion at the root of the welds over a zone varying in width from 1/16 to 1/32 inch on the four welds. Too low a current was used in the welding."

Here the lack of fusion and penetration at the root is proportionately more serious in the 5/16 in. weld than it would be if the weld were larger.

SERIES 2100 AND 2300, FIG. 18

These are forms of side welded joint. While they have less average strength than the end-welded series, both sym-

path through the bars.

*Faying: The term "faying" is borrowed from shipbuilding parlance as a convenient term to denote the surfaces in contact.

SERIES 2100 AND 2300, FIG. 18

These are forms of side welded joint. While they have less average strength than the end-welded series, both sym-

metrical and non-symmetrical specimens show remarkably close grouping of results. The difference in strength between corresponding specimen groups averages only 11 per cent in favor of the symmetrical series. The ability of Series 2100 to resist bending induced by eccentricity is due to its faying surfaces being restrained from separating by the location of the welds.

All specimens failed through the minimum section (throat) of the fillet. The great majority of the lower strengths were in specimens welded by two shops (Y and KZ). The welder of one of these shops was in Class II of the Qualification Tests, and the other welder was not qualified under the Committee's specifications.

SERIES 2200 AND 2400, FIG. 19

Series 2200 is a non-symmetrical, and Series 2400 a symmetrical form of side welded joint. Both series show a slight decrease in strength as the bars increase in thickness from the 33 to the 63 groups. This may be due to either one or both of the following: An increase in bar thickness with a corresponding increase in the eccentricity upon the weld; or a less uniform distribution along the weld as its length increased. The character of the stress distribution is shown in Fig. 33, in which the strain lines appear at the ends of the weld as the loading increases.

Symmetrical groups average 9 per cent stronger than the corresponding non-symmetrical groups. All weld failures in both series occurred through the throat of the weld, as illustrated in Fig. 34.

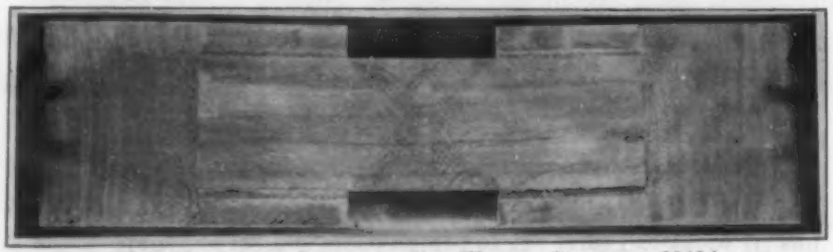


FIG. 33—STRAIN LINES ON SIDE WELDED SPECIMEN 2243A

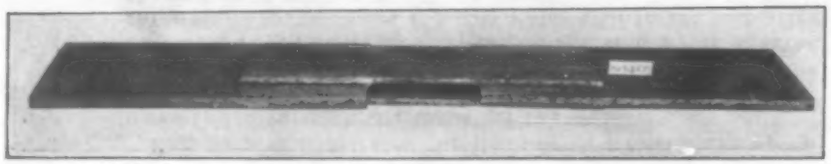


FIG. 34—TYPICAL FAILURE THROUGH THROAT—SPECIMEN 2453AZ

SERIES 2500, 2600, 2700 AND 2800, FIG. 19

These are forms of joint in which end and side welds are combined. The last three of these series show the same decrease in strength from the 33 to the 63 groups as was observed in Series 2200 and 2400, but Series 2500 slightly reverses the trend from groups 53 to 63. Unit strength is intermediate between those of corresponding side and end welded joints.

Groups of the symmetrical Series 2700 and 2800 are 15 per cent and 13 per cent, respectively, higher in strength than the corresponding non-symmetrical groups of series 2500 and 2600. It should be noted that although the specimens may be classed as symmetrical, the b bars are subjected to some eccentric pull due to the location of the fillet. Under a tensile load the b bars bow in, and retain a permanent set after passing the elastic limit of the steel. When failure occurs in the weld and the load is released, the amount of such set may be measured by the distance between the original and final positions of the bars. (Fig. 35.)

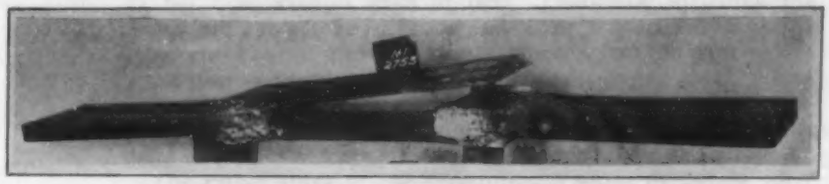


FIG. 35—BENDING IN SYMMETRICAL SPECIMEN 2753N

FIG. 36
TYPICAL FAILURE
IN
COMBINED WELDS

Fig. 35 also illustrates the manner in which these specimens failed through the throat of the weld.

In Series 2800, 15 of the 31 specimens failed in the bar. Where fracture took place in the weld, in all four series, the end weld ruptured first, after which the side welds sheared through. Fig. 36 shows the side welds still intact just after the end weld fractured.

The two low points in each of groups 2663 and 2863, which failed in the bar, were welded by the same two shops (C and Q). Since these specimens failed at much lower loads than the average of the groups, it is possible that the material used may have been taken inadvertently, from the shops' own stock.

SERIES 2900 TO 4300 INCLUSIVE, FIGS. 20 TO 24

In these butt welded forms of joint the average strengths, per unit of throat area, in the different forms and sizes of welds are nearly uniform. The ¼ in. square welds show a higher strength than the ⅜ in. square; the ½ in. single vee is slightly stronger than either the ⅜ or ¾ in. single vee; and in the double vee, the ½ in. is slightly stronger than the ¾ or 1 in.

As between different forms of the same size no apparent difference is noted, nor is any difference in unit strength observed between intermittent and continuous welds.

Poor penetration and fusion explains most of the low points on the graphs. Failure to penetrate into the root of the vee is observed in all of the specimens showing the lowest strengths (Fig. 37). Contrast the appearance of these welds with those in Fig. 38, all of which showed high strength.

It is interesting to note that of the ten single and double vee series, in nine the lowest strength of all the specimens occurred in a ¾ in. weld. These nine specimens were made

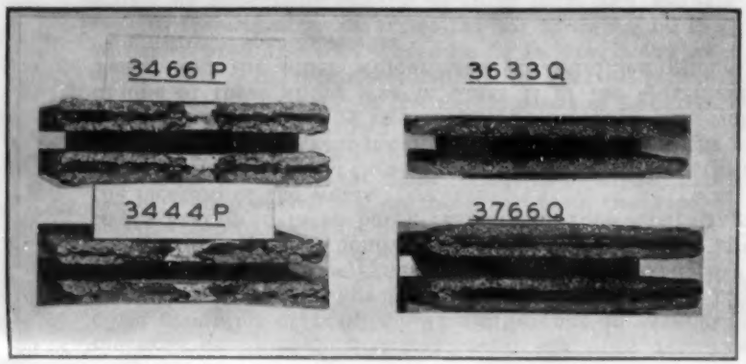


FIG. 37—LOW STRENGTH BUTT WELDS

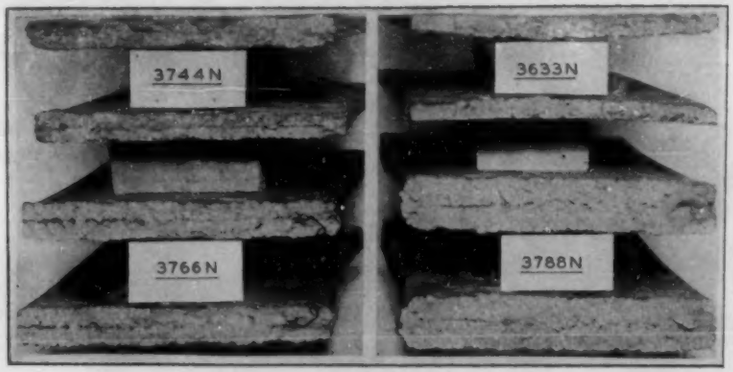


FIG. 38—HIGH STRENGTH BUTT WELDS

by seven welders who are representative of the best and poorest of those qualified.

The Luder lines at the intermittent welds of Series 3800, 3900 and 4000, are curious. Fig. 39 shows that at increasing loads the outer welds appear to be most stressed and yet failure occurred first in the center weld. A suggested explanation is that the edges of the bars distort more freely than the center, thus throwing more stress on the center weld; but the stress in the center weld is distributed over a 17 per cent greater area of bar. Therefore, although the total stress in the center weld may be greater than in either of the outer welds, the Luder lines emanating from it do not become visible to the same extent as do those at the outer welds.

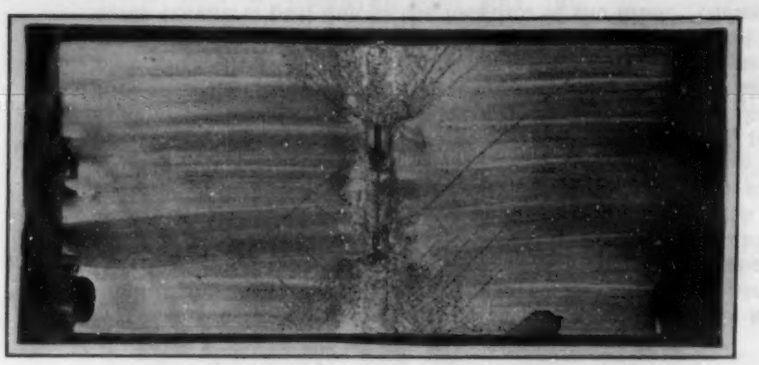


FIG. 39—TYPICAL FAILURE—SERIES 3800, 3900, 4000

FIG. 37—Low Strength Butt Welds

FIG. 39—Typical Failure—Series 3800, 3900, 4000

SERIES 4400 TO 5200 INCLUSIVE, FIG. 25

These are butt-welded forms of joint in which the weld is subjected to both tension and shear. Since only 17 of the 60 specimens failed in the weld, no definite conclusions as to weld strength can be drawn. At the average weld strength of 40 kips per sq. in., the outer weld produces a stress across the corner of the bar of approximately 57 kips per sq. in. The condition is further aggravated by the high concentration of local stresses in the corners. (Fig. 40.)

The analogy of combined welds, Series 2500 to 2800, tends to confirm the correctness of the usual assumption that the resultant strength of a diagonal weld may be resolved into its rectangular components.

As the weld length increases from 1 in. in groups 4422, 4744 and 5088, to 2 in. in groups 4533, 4844, and 5188, and to 3 in. in groups 4622, 4944 and 5288, it will be observed that the points become more closely grouped together. This is apparently due to the fact that a small error in measuring the length of a short weld affects the unit value to a greater extent than where the same error is made in measuring a longer weld.

FIG. 40—Typical Failure—Diagonal Butt Weld Specimen

SERIES 5500, 5600, 5700, 5900, 6000 AND 6100, FIG. 26

Series 5500 and 5600 were intended to typify the web splice of a plate girder, and Series 5700 to 6100 the connection of web to flange.

The form of these specimens invited failure through the bar rather than through the welds. The center of gravity of the b bar was so far from the axis of pull that severe bending resulted. The butt welded specimens failed as shown in Fig. 41.

In the fillet welded series the non-symmetrical specimens were subjected to a large amount of bending. Even the symmetrical specimens bowed in, the flange of the tee providing insufficient stiffness. Various failures are shown in Fig. 42.

FIG. 41—Typical Failure—Butt Welded Split Beam Specimen

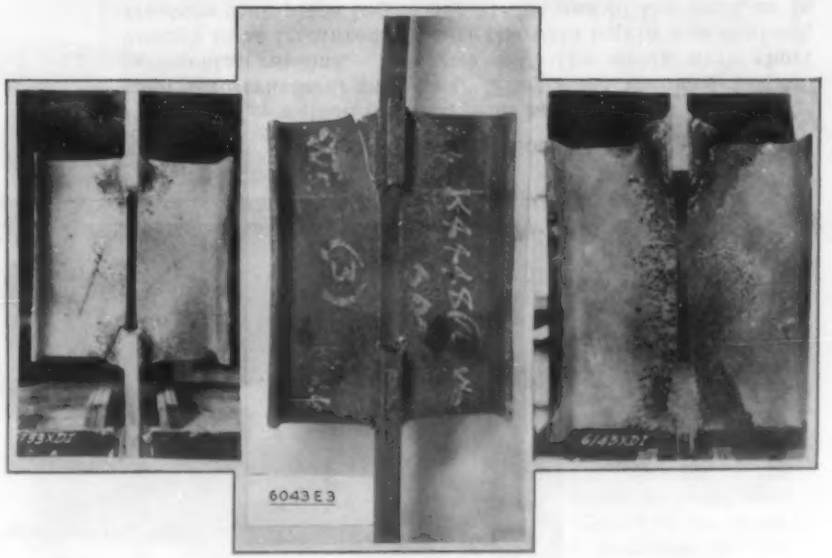


FIG. 42—Typical Failures—Fillet Welded Split Beam Specimens

SERIES 6200, 6300, 6400 AND 6500, FIG. 27

These series were intended to typify one form of wind bracing connection between beams and columns. It need hardly be pointed out that a plate welded on one side only (Series 6200 or 6400) may be considered the equivalent of Series 6300 or 6500, when excessive prying action on the weld is restrained by an adequately supported beam.

These series offer an outstanding example of the effect of eccentricity upon welds. The symmetrical specimens are approximately 100 per cent stronger than the non-symmetrical. In all cases the weld failed, not through the throat, but along the leg next to the b bar (Fig. 43). The welds were subjected to both tension and prying, the effects being cumulative.

Some of the specimens welded on one side only had c bars which became warped out of line during cooling. The extent of this distortion is shown in Fig. 44. The resistance to bending offered by these welds is so small that it becomes quite important to avoid the slightest eccentricity with its resultant prying action on the weld.

The low strength of group 6323 is due to extremely poor fusion and penetration at the root of the welds.

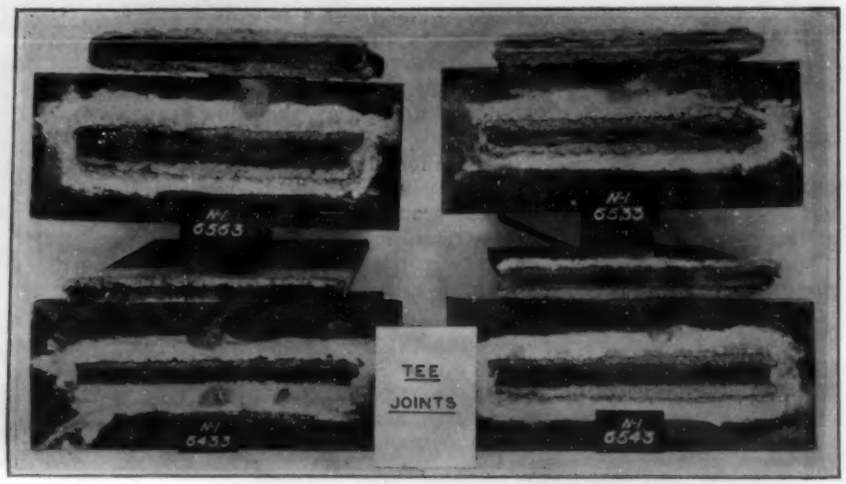


FIG. 43—TYPICAL FAILURES—TEE JOINTS

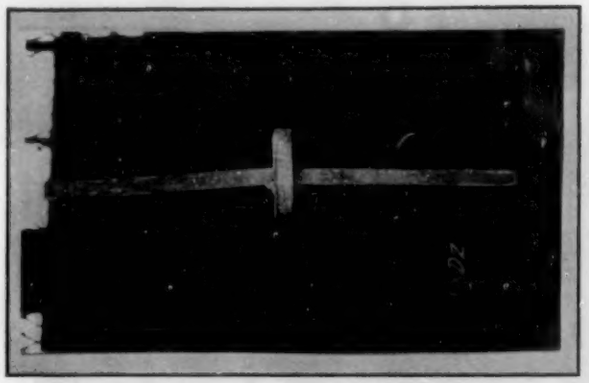


FIG. 44
DISTORTION OF c BAR DUE TO COOLING. SPECIMEN 6263XD2

SERIES 6800 AND 6900, FIG. 28

These edge welded forms of joint have not been extensively used for structural purposes. They were included for experimental reasons. In series 6800 the welds were short enough to be fractured. Where the weld length was doubled, fracture took place in the bar at one end of the weld, as in Fig. 45. These specimens, 6921 DR 1, 2, 3 are marked by the laboratory with the ultimate load on No. 1 and No. 3, and with the yield point load on No. 2. It will be seen that the bars tended to curve away from each other and that considerable necking took place at the fractured section.

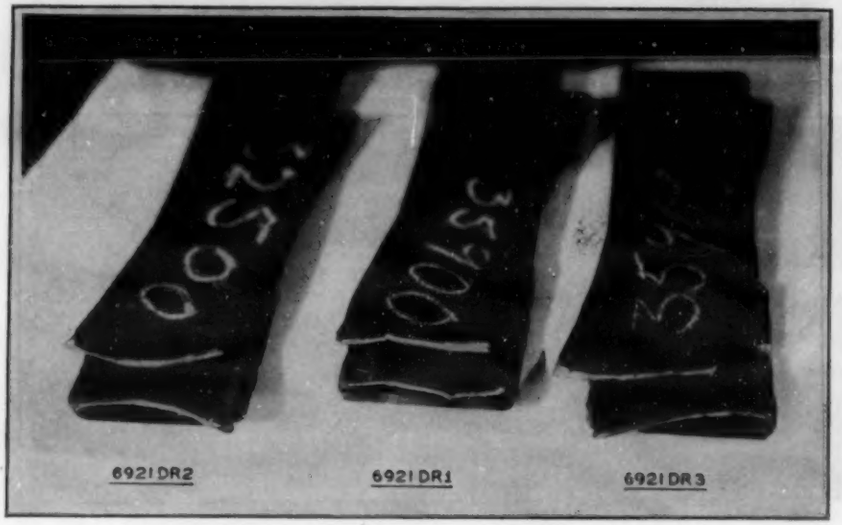


FIG. 45—TYPICAL FAILURES—SERIES 6900

FIG. 43—TYPICAL FAILURES—TEE JOINTS

FIG. 45—TYPICAL FAILURES—SERIES 6900

5-3-1 SPECIMENS WHICH FAILED IN BASE METAL

Specimens which failed in the base metal were carefully examined. Reports from the laboratories showed that failure occurred at sections remote from the weld. That failure was not started by the effects of the thermal action of the arc or torch is indicated in Table V, where the ultimate strength of the base metal in specimens not subjected to much bending (such as the butt weld series) is observed to vary not more than 5 per cent from the ultimate strength of the base metal reported in Appendix 10-1.

TABLE V

EFFECT OF WELDING ON BASE METAL

Butt Weld Specimens That Failed in Bar	Ult. Strength (Kips/In.²) of Base Metal			Mill	
	Welded Specimen	Coupon		Symbol	Heat Number
		Bur. of Stands.	Mill		
2922 N	62.4	58.9	59.4	C	313424
2922 HY-1	53.2	58.9	59.4	C	313424
2922 HY-2	56.9	58.9	59.4	C	313424
3533 AZ	58.6	56.1	58.7	I	22598
3633 AZ	55.2	56.1	58.7	I	22598
3644 D	51.2	59.1	59.6	B	41V240
*3666 Q	43.0*	62.5*	59.6*	C	313424
3744 AZ	58.3	58.8	62.2	I	21641
3766 AZ	52.8	54.6	56.8	I	22598
4233 AZ	57.7	56.1	58.7	I	22598
4244 AZ	54.6	Avg. 55.4	Avg. 58.6	I	22598
4344 AZ	54.8	Avg. 55.4	Avg. 58.6	I	22598
4366 AZ	52.7	54.6	56.8	I	22598
4388 AZ	56.4	57.4	57.9	I	21641
Average 13 Specimens	55.8	57.0	58.8		

Difference in Strength between Welded Specimens and Bur. Standards Coupons	—2.1%
Difference in Strength between Welded Specimens and Mill Coupons	—5.1%

*Specimen not included in average (See comment on 2663—Section 5-3 page 68)

5-4 PLANES OF REFERENCE

In order to classify the different kinds of joint, all specimens have been referred to three coordinate planes, as shown in Fig. 46. The X- and Y-planes are the vertical planes passing through the longitudinal and transverse center-lines, respectively, of the specimens, and the Z-plane passes horizontally through the center line of the c bars.

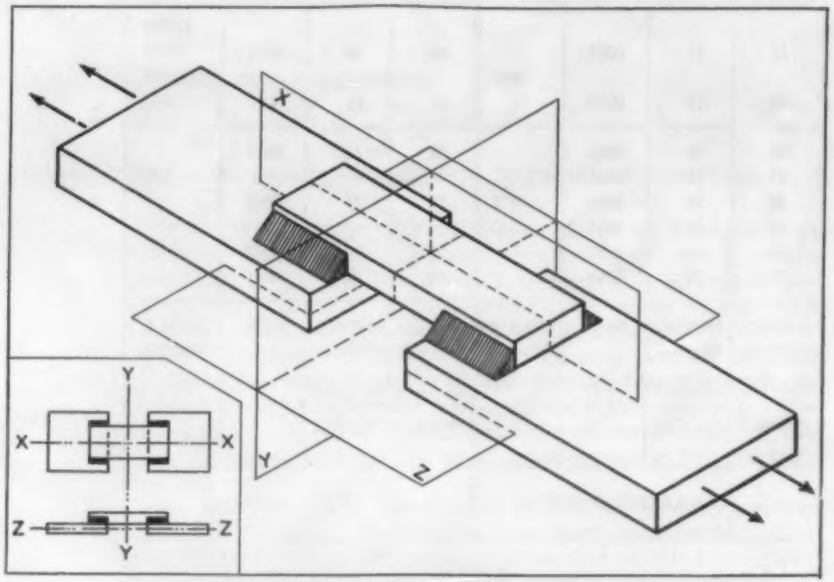


FIG. 46—PLANES OF REFERENCE

5-5 FILLET WELDS

A survey of the types of design for fillet welded specimens, which for convenience are assembled in Table VI with arrows indicating direction of pull, shows that they differ in several respects, and these differences are reflected in the test results. Series 5500 and 5600, butt welds in shear, and Series 6800 and 6900, edge welds, are also listed in the table. These non-fillet welded joints have been included for the reason that their form, as well as behavior, is very similar to that of other series in the table.

TABLE VI

FORMS OF JOINT WITH WELDS IN SHEAR

FORM OF JOINT	SERIES	FORM OF JOINT	SERIES
c b c bar bar bar End weld one bar	1000 1100 1200	c b c	5700 5900
End weld both bars	1300 1400 1500 1600 1700 1800		6000 6100
End weld	1900 2000		6200 6400
Side weld	2100 2200		6300 6500
Side weld	2300 2400	Butt weld in shear	5500 5600
Combined weld	2500 2600		
Combined weld	2700 2800	Edge weld	6800 6900

5-5-1 CLASSIFICATION BY PLANES

Regarding the arrangement of the bars, all specimens, except Series 6800 and 6900, are symmetrical about the X-plane and the Y-plane. About the Z-plane some specimens are symmetrical and some are non-symmetrical.

A further difference is to be noted between specimens, both symmetrical and non-symmetrical, in regard to the disposition of the metal in the b bars with reference to the Z-plane. In some cases the distance from the center of gravity of the b bar to the Z-plane is small, while in others it is quite large. It was expected that the latter condition would produce excessive local bending in the bars and the tests confirm this to an even greater extent than had been anticipated.

Regarding the location of the welds there are further differences. All specimens are symmetrical about the X- and Y-planes. About the Z-plane some are symmetrical and some non-symmetrical. All specimens non-symmetrical in bar arrangement are non-symmetrical in weld location, but here an important distinction is found. In some cases the welds are located at, or extended up to, the ends of both b and c bars, and in other cases at the ends of only the b bar. The latter location might be expected to produce a serious prying action on the weld due to the bending of the bars, as was borne out by the tests.

TABLE VII

STRENGTH OF FILLET WELDED JOINTS WITH NEGLIGIBLE ECCENTRICITY

SYMMETRICAL				NON-SYMMETRICAL			
		Kips/Sq. In. Throat				Kips/Sq. In. Throat	
Location of Welds	Series	*Average Ultimate	Minimum Ultimate	Location of Welds	Series	*Average Ultimate	Minimum Ultimate
End	1900	52	33	End	1300	46	40
	2000	53	36		1400	49	45
					1500	52	35
Side	2300	41	32		1600	46	36
					1700	51	42
	2400	37	32		1800	43	34
End and Side (Combined)	2700	43	36	Side	2100	37	28
	2800	40	34		2200	34	27
End (Tee)	6300	37	25	End and Side (Combined)	2500	38	33
	6500	37	30		2600	36	30
Weighted Average 349 Specimens		43.0		Weighted Average 412 Specimens		42.3	
Weighted Average 761 Specimens = 42.5							

*Specimens that failed in bar included in average.

confirm this to an even greater extent than had been anticipated.

*Specimens that failed in bar included in average.

5-5-2 CLASSIFICATION BY RESULTS

Even a superficial study of Figs. 15 to 19, and 26 to 28, where the behavior of each specimen is graphically indicated, shows that the results fall naturally into two classes, those with negligible, and those with considerable eccentricity.

5-5-2-1 Characteristics of Joints with Regard to Eccentricity

JOINTS WITH NEGLIGIBLE ECCENTRICITY

In this class, which is listed in Table VII with averages and minima for each series, occur the forms of joint that are not subject to prying effect. (See footnote, page 48.) The class includes specimens in which the centers of gravity of the b bars are near the Z-plane, and which, if non-symmetrical, have welds located (1) across the ends of both b and c bars, (2) along the sides of the b bar and extending up to the end of both bars, or (3) across the ends and along the sides of the b bars. In all these forms there was a negligible amount of bending across the weld.

TABLE VIII

STRENGTH OF JOINTS WITH CONSIDERABLE ECCENTRICITY

NON-SYMMETRICAL				SPLIT BEAM AND EDGE SPECIMENS		
		Kips/Sq. In. Throat		All Specimens Failed in Bar		
Location of Welds	Series	*Average Ultimate	Minimum Ultimate	Location of Welds	Series	Average Ultimate Kips/Sq. In. Throat
End	1000	38	26	Edge (Butt Welds In Shear)	5500	30
	1100	42	31			
	1200	43	25		5600	25
End (Tee)	6200	22	12	Side (Fillet Welds In Shear)	5700	23
	6400	20	12		5900	27
					6000	27
					6100	31
Edge	6800	43	34	Edge	6900	44

*Specimens that failed in bar included in average.

JOINTS WITH CONSIDERABLE ECCENTRICITY

In this class, listed in Table VIII, occur the forms of joint that are subject to prying effect. The class includes specimens in which the centers of gravity of the b bars are remote from the Z-plane, as well as those non-symmetrical forms in in which the welds are located at the ends of only the b bar. Series 6800 and 6900 are included on account of the eccentricity of the c bars. In all these forms there was considerable bending, which caused failure to occur in the bars or induced excessive prying on the welds.

5-5-3 ANALYSIS OF RESULTS

5-5-3-1 Safety Factors for Joints with Negligible Eccentricity

In connection with the specimens listed in Table VII, it was observed that the ultimate unit strength varied within moderate limits for the several series. The averages per square inch of weld throat ranged from 34 to 53 kips and the individual minima from 25 to 45 kips. Attempts to rationalize these results so as to warrant a more detailed classification were found to involve factors whose magnitude is less than the difference between individual welders. The Committee, therefore, concluded that all specimens of the class in question should be considered as one group for purposes of valuation.

The question as to what value should be used as a reference in comparing test results was next considered. The Committee found it advisable to recognize existing practices as far as possible. A working value of 11.3 kips per sq. in. has been generally used with satisfactory results in the design of many structures erected since the inception of this investigation. Its convenience, when referred to fillet sizes, is well known. A factor of safety of 3-1/3 is commonly accepted in structural design, that is, steel whose ultimate strength averages 60 kips is subjected to a working stress of 18 kips. Therefore it would have been consistent and proper to divide the average ultimate unit strengths of the welded specimens by 3-1/3 in order to determine corresponding working loads. The same result was effected more conveniently by reversing the process, i.e., computing the respective factors of safety as referred to a working stress of 11.3 kips.

In Table IX the series are re-listed and the factor of safety that would result in each case, as referred to a working stress of 11.3 kips, is indicated.

TABLE IX

SAFETY FACTORS FOR FILLET WELDED JOINTS WITH NEGLIGIBLE ECCENTRICITY

SYMMETRICAL				NON-SYMMETRICAL			
Location of Welds	Series	Factor of Safety Based on Stress of 11.3 Kips/Sq. In. Throat		Location of Welds	Series	Factor of Safety Based on Stress of 11.3 Kips/Sq. In. Throat	
		Average	Minimum			Average	Minimum
End	1900	4.63	2.92	End	1300	4.09	3.54
	2000	4.70	3.18		1400	4.36	3.98
					1500	4.55	3.10
Side	2300	3.62	2.84		1600	4.06	3.18
	2400	3.28	2.84		1700	4.48	3.72
					1800	3.81	3.02
Side and End (Combined)	2700	3.82	3.18	Side	2100	3.30	2.48
	2800	3.54	3.02		2200	3.01	2.39
End (Tee)	6300	3.28	2.21	Side and End (Combined)	2500	3.36	2.92
	6500	3.31	2.66		2600	3.18	2.66
Weighted Average for 349 Specimens		=3.80		Weighted Average for 412 Specimens		=3.74	
Weighted Average = 3.76 for 761 Specimens							

It will be observed that for the

SYMMETRICAL SPECIMENS

Average factor of safety varies from 3.28 to 4.70, average 3.80.
Minimum " " " " " 2.21 to 3.18

NON-SYMMETRICAL SPECIMENS

Average factor of safety varies from 3.01 to 4.55, average 3.74.
Minimum " " " " " 2.39 to 3.98

5-5-3-2 **Safety Factors for Joints with Considerable Eccentricity**

Joints in this classification are those listed in Table VIII. The specific values reported do not furnish a basis for design, for it would palpably be improper to exterpolate these strengths as a guide to the effect of bending in joints having other dimensions. The effect of such bending must be analyzed for each design, as is now done in riveted work.

The specimens using tees made by splitting I-beams were included as typifying web splices and the connections of web to flange in girders as a check on the more elemental type of joint. It was thought that the flanges of the tees might provide sufficient stiffness in the joint to cause failure in the welds. However, shearing stresses combined with excessive bending in the tees caused failure to occur in the base metal and so gave no data on the absolute strength of the weld. The Committee was unsuccessful in designing a specimen that would exactly typify the connections in question. Even in full size girders other factors would probably render it difficult to determine with any exactness the magnitude of unit shear in these connections.

5-6 BUTT WELDS (TENSION)

5-6-1 CLASSIFICATION BY PLANES

The joints of Series 2900 to 4300, Figs. 20 to 24, which exclude the diagonal joints, comprise square, single vee, and double vee butt welds, both continuous and intermittent. In all these joints the weld is at right angles to the direction of pull. Referring to the same planes mentioned in Section 5-4, all specimens are symmetrical about both X- and Y-planes. About the Z-plane, it is only the double vee weld that is symmetrical. The square and the single vee welds are non-symmetrical. In these non-symmetrical specimens, however, the eccentricity is so small that it may be safely disregarded.

5-6-2 ANALYSIS OF RESULTS

A marked similarity is observed in the behavior of all the different forms of joint, the curves in Fig. 20 being almost identical with those in Figs. 21 to 24 inclusive. While the dispersion of points is somewhat greater than in the case of fillet welds, the average ultimate strength is uniformly high.

Average factor of safety varies from 3.01 to 4.36, average 3.74.
Minimum " " " " " 2.39 to 3.98

fillet welds, the average ultimate strength is uniformly high.

5-6-2-1 **Intermittent and Continuous**—The average strengths of the series are shown in Table X. Although the continuous welds appear to be stronger than the intermittent, the difference between the highest and lowest strengths is only about 5 per cent. The unit strengths of intermittent and continuous welds in these tests may be considered equal.

TABLE X

EFFECT OF CONTINUITY ON STRENGTH OF BUTT WELDS

Weld	Total Length of Weld	Series	*Average Ultimate Strength Kips/Sq. In. Throat
Continuous	4"	2900–3000–3100	48.7
Intermittent	6"	3200–3300–3400	48.6
Continuous	7½"	3500–3600–3700	49.7
Intermittent	9"	3800–3900–4000	48.1
Continuous	11½"	4100–4200–4300	50.7

*Specimens that failed in bar included.

5-6-2-2 **Square, Single Vee and Double Vee**—The average strengths of the different sizes and forms of welds are assembled in Table XI.

TABLE XI

EFFECT OF FORM AND SIZE ON STRENGTH OF BUTT WELDS

Form of Weld	*Avg. Ultimate Strength (Weighted)—Kips/Sq. In. Throat				
	Size of Weld—Inches				
	¼	⅜	½	¾	1
Square	54.1	48.2			
Single Vee		48.6	50.2	46.9	
Double Vee			51.1	46.9	50.2
Weighted Average of All Specimens (293) = 49.6 Kips/Sq. In.					

*Specimens that failed in bar included.

5-6-2-2-1 Effect of Form of Weld—For the same bar thickness, weld strength was not affected by the form of weld, which depends on the manner in which the bars are prepared for welding. A maximum difference of 2 per cent is observed between the strengths of the ½-inch double and single vee welds. This difference is so slight as to be negligible.

5-6-2-2-2 Effect of Weld Size

SQUARE

The greatest disparity in strength per sq. in. is exhibited by square joints, of which the ¼-inch welds average 12 per cent stronger than the ⅜-inch welds. This may be explained either by better fusion in the smaller weld; or by a proportionately greater reinforcement, reference to the table of reinforcements in Section 2-5-9 indicating a ratio of total weld thickness to bar thickness 12½ per cent greater for the ¼-inch than for the ⅜-inch weld.

SINGLE VEE

The ½-inch welds are approximately 7 per cent and 3 per cent stronger respectively, than ¾-inch and ⅜-inch welds. The increase in strength of the ½-inch over the ⅜-inch welds may be the result of the former having been deposited in two layers, the second serving to refine the metal already deposited. The lower unit strength of the ¾-inch welds may be the result of poorer penetration and fusion at the root of the vee due to its depth.

DOUBLE VEE

In this form of weld also, the ½-inch welds are strongest, being approximately 9 per cent and 2 per cent higher, respectively, than the ¾-inch and 1-inch welds. The apparent abnormality may be explained by considering a double vee as two single vees. It is then noted that the unit strength of a ¾-inch double vee, consisting of two ⅜-inch single vees, approximates that of the ⅜-inch single vees tested, and that the unit strength of a 1-inch double vee, consisting of two ½-inch single vees, is identical with that of the ½-inch single vees tested.

5-6-2-3 **Safety Factors**—As in the case of fillet welds, the Committee has taken cognizance of existing structural practice, and accordingly has summarized and presented in Table XII the data for each series. Average series strengths and minimum individual strengths are given to the nearest kip, and the equivalent factors of safety listed are referred to a working value

of 13 kips per sq. in. of weld throat as allowed by the American Welding Society's Code for Fusion Welding and Gas Cutting in Building Construction.

TABLE XII

SAFETY FACTORS FOR BUTT WELDED JOINTS

Joint	Weld	Series	*Ultimate Strength Kips/Sq. In. of Throat		Factor of Safety Based on 13 Kips/Sq. In.	
			Average	Minimum Individual	Average	Minimum
4" Continuous	Square	2900	50	39	3.84	3.00
	Single Vee	3000	47	33	3.62	2.54
	Double Vee	3100	50	39	3.84	3.00
7½" Intermittent	Square	3200	50	44	3.84	3.38
	Single Vee	3300	49	42	3.77	3.23
	Double Vee	3400	48	40	3.70	3.08
7½" Continuous	Square	3500	50	45	3.84	3.46
	Single Vee	3600	50	31	3.84	2.38
	Double Vee	3700	50	36	3.84	2.77
11½" Intermittent	Square	3800	48	35	3.70	2.67
	Single Vee	3900	48	39	3.70	3.00
	Double Vee	4000	49	39	3.77	3.00
11½" Continuous	Square	4100	54	47	4.15	3.62
	Single Vee	4200	50	39	3.84	3.00
	Double Vee	4300	50	39	3.84	3.00
Weighted Average			49.6	39.1	3.81	3.01

*Specimens that failed in bar included.

The weighted average ultimate strength of the 293 butt welded specimens is 49.6 kips per sq. in. corresponding to a safety factor of 3.81. With regard to the minimum, only 10 specimens showed a safety factor of less than 3. These specimens are listed below in Table XIII each with its safety factor indicated.

TABLE XIII

INDIVIDUAL BUTT-WELDED SPECIMENS WITH FACTOR OF SAFETY LESS THAN 3

Specimen	Welder	Ultimate Strength Kips/Sq. In. Throat	Factor of Safety Based on 13 Kips/Sq. In. Throat
3033	BY-B	35.8	2.75
3066	DY-A	32.6	2.50
3666	CZ-A	31.0	2.38
3766	Q-B	36.2	2.78
3833-3	B-A	34.7	2.67
3833-1	B-A	37.4	2.86
3966-1	DY-A	38.8	2.98
3966-2	DY-A	38.8	2.98
4066	GZ-A	38.9	2.99
4266	GZ-B	38.8	2.98

Of these 10 specimens, four had safety factors nearly equal to 3; the remaining six varied from 2.38 to 2.86. It will be noted that seven specimens were ¾-inch welds, and three were ⅜-inch welds.

An examination of the photographs of some of these specimens (Fig. 37) clearly brings out the reason for their lower strengths. The magnitude of these strengths is remarkable in view of the lack of penetration at the roots.

5-7 BUTT WELDS (TENSION AND SHEAR)

The diagonal butt weld joints of Series 4400 to 5200, Fig. 25, were included in the hope that the results would indicate whether or not the conventional method of resolving a diagonal stress into its two components could be followed by assigning to the tension and shear components their proper working values.

In designing the specimens, the extent to which the stress across the corner of the bar would exceed that in the weld was not realized, and as a consequence nearly all the specimens failed through the bars, as illustrated in Fig. 40. No conclusion as to unit values should be drawn from these tests.

If the specimens were re-designed in the light of present knowledge, placing the welds far enough away from the edges of the plate to prevent overstressing the corners, it is believed that failure might then take place in the weld.

(Report to be continued in next issue)

Lead Welding

By **OWEN C. JONES**

✦Mr. Jones is connected with the Publicity Department of the Linde Air Products Co.

FABRICATION OF LEAD EQUIPMENT SIMPLIFIED BY OXYACETYLENE PROCESS

LEAD is used by the process industries for lining vats and tanks as well as for many types of piping and special equipment where corrosion is best resisted by this element. Wherever sulphuric acid, sulphur dioxide, or acid fumes have to be used, stored or conveyed, lead-lined vessels and lead pipe are almost exclusively used. The fabrication of these containers and pipe systems has been made easy by the use of the oxy-acetylene lead-welding process.

Being a true welding operation, lead welding can be done most satisfactorily with oxy-acetylene welding equipment. Because of the low melting point of lead, only a very small flame is required, and it is consequently possible to use a small blowpipe designed specially for lead welding. The technique is somewhat different from that required for steel, but the difference is hardly any greater than between steel and aluminum for example.

The dull gray surface appearance of lead is due to a coating of oxide and other compounds that must be carefully removed before welding. For preparing the edges and surface, prior to welding, special tools known as "scrapers" are available. The metal is so soft that the preparation of pieces for welding is a relatively simple matter. The main point is to clean the surface so that thorough fusion will result.

As regards welding, the most characteristic property of lead is its low melting point. This permits fusion by means of a very small flame. In fact, lead melts so easily even with a small flame, that the technique of blowpipe manipulations is quite different from that used with any other metal. Best results are obtained with a flame containing a slight excess of acetylene.

In welding lead, hold the blowpipe so the flame is perpendicular to the surface of the work, and with the inner cone almost touching the surface of the metal, heat the lead until it just melts, then lift the blowpipe quickly in order to prevent excess melting. The blowpipe flame is directed on the metal for an instant and quickly flipped away. In this way it is possible to control this easily fused metal. Light lead sheet with flanged edges may be welded without the addition of rod, but for most work additional metal is required. Welding rod may be made by cutting sheet lead into strips or by melting lead in the vee of a short length of angle iron to form a bar of the size desired.

In most work with sheet lead, such as tank linings, lap joints are used, with a well-cleaned overlap of ¼ to ½ in. Often forms are necessary to support the sheet, as the metal is too soft to remain in position unsupported. After the lap is in position, the joint should be tapped lightly with a wooden mallet in order to cause closer contact of the sheets. Each edge of the lap is then fillet-welded, using rod.

When it is not possible to work from both sides, as for example, when a lining must be made in place, the butt-weld is preferable. The lead sheets must then be supported in position, and tack-welded to maintain alignment. Vertical seams should be started at the bottom, the work progressing upward.

Lead pipe may be very easily made from sheet lead by cutting to size, shaping around a wooden or metal form, and then welding the longitudinal seam.

Recently a plant in the process industries had occasion to make several small tanks for storing sulphuric acid. These tanks were covered with steel shells to support and protect the soft lead lining. One such tank, used to collect acid fumes prior to dispersal through a ventilating chimney, was constructed in this manner. The inner lining was made up of 3/16-in. sheet lead. A 3/16-in. steel shell and stand were also fabricated by welding. The piping for this tank, as well as over 10,000 ft. of pipe used in connection with alcohol extractors, was all fabricated by welding. Sheet lead was rolled to the required thickness, and then the longitudinal seams were welded.

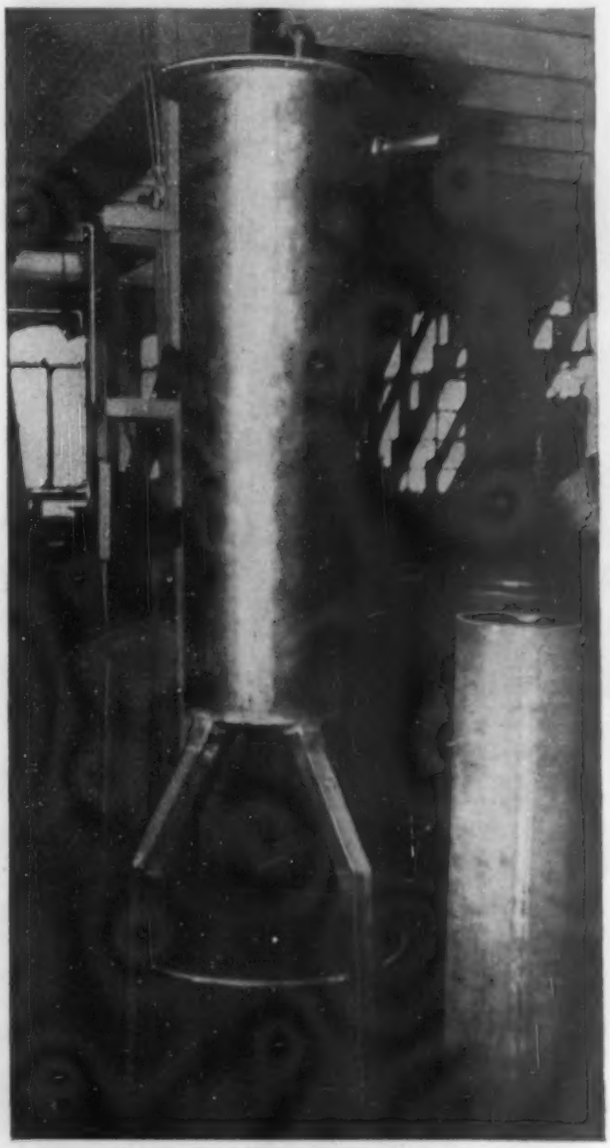


Fig. 1—Lead Lining Steel Shell and Stand, All Welded

(Report to be continued in next issue)

specimens are listed below in Table XIII each with its safety factor indicated.

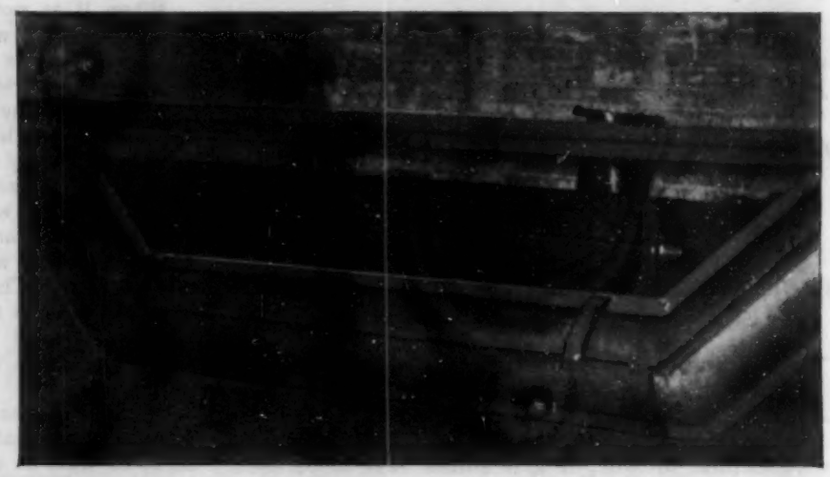


Fig. 2—Oxy-Acetylene Welded Lead Piping, Supported with Welded Angle Iron Guards

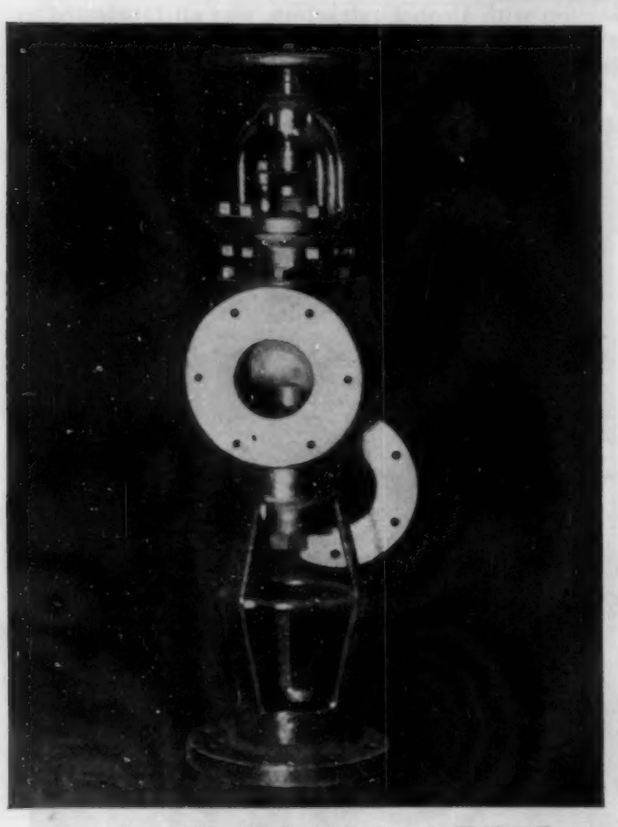


Fig. 3—Special Valve Lined with Lead at the Welding Shop

After this lead piping was welded in place, an angle iron framework made up in halves by welding, was bolted around the lead pipe, to act both as a support and as a protection against injury.

The welding shop was also called upon to fabricate a lead-lined valve for use in connection with this lead piping. Using an oxy-acetylene lead welding blowpipe, lead was applied to all inner surfaces, until the entire inside of the valve, in both open and closed positions, had a solid lead lining. The unique part of this job was that a lead-lined valve of the type desired could not be obtained ready-made and it was necessary for the plant welder to do the entire job himself. This shows that, with a little ingenuity and close adherence to correct procedure, an oxy-acetylene welder can often fabricate parts that cannot be bought as standard equipment.

This plant is typical of many throughout the country in which lead welding is not considered a specialty but merely part of the routine work.

Engineering Abstracts on Welding

Reprinted from Bulletin published by The Institution of Civil Engineers, London

Tests on Reinforced-Concrete Beams with Welded Reinforcement

A SERIES of eight beams were made and tested in order to study a new form of shuttering in which the webs of T-beams are made with perforated sheet-iron which is left on permanently, instead of timber shuttering. The iron sheets are placed with the rough side projecting, and thus serve as a key for the plaster, as well as acting as reinforcement. The beams tested were 8.85 ft. long, with a top flange 15 in. wide and 4 in. thick; the depth of the beam was 12½ in. and the thickness of the web 2½ in. in the case of the eight specimens with perforated sheet reinforcement, and 6¼ in. in the case of the twenty specimens with welded rod reinforcement. The beams were tested on a span of 7.9 ft. under loads applied one-third of the span from either end. Details are given of the reinforcement. The author concludes that the perforated sheet-iron shuttering, whether in one piece or welded, and whether alone or with round rod reinforcement, acts efficiently as tension and shear reinforcement almost up to the point of failure. In the majority of beams investigated the use of welded bars has produced no notable reduction in the strength. Only in the case of welded rods ¾-in. diameter was a marked reduction in the strength caused by the premature failure of a weld: even in this case the calculated stress in the steel was beyond the safe yield stress. R. SALIGER. (**Beton und Eisen*, 29, 305-309.)

Fatigue Tests of Cast-Iron Welds

The author describes bending fatigue tests made on cast iron and, for comparison, also on mild steel, both in the natural condition and after welding.

The results of two pairs of fatigue tests indicate that the fatigue properties of cast iron are reduced by about 20 per cent by welding It also appears that in both static tests and fatigue tests the cast iron dealt with was about three times as strong, when tested as cast, as when tested after machining.—W. B. BARTELS. (*Ver. deu. Ing.* 74, 1423-1426.)

Arc Welding of Mild Steel

Notched-bar tests indicate that arc welds without protection against oxidation are much weaker than those in which a coated electrode has been used. In the former the fractures are always crystalline throughout the thickness, whereas the latter are very lightly crystalline, and that only in the center. Metallographic examination indicates that the grain of the protected weld presents more regular forms than that of the unprotected weld, but the difference is not very definite. Under X-ray examination unprotected welds reveal feeble orientation of stress-lines and very pronounced asterism, whereas protected welds exhibit each distinct orientation but are only very feebly striated with asterism. The authors state that X-ray diagrams indicate positively the existence of tensions in non-protected welds.—D. ROSENTHAL and M. MATHIEU. (*C. R.* 191, 484.)

Tests on Concrete Columns with Welded High-Tensile Steel Reinforcement

The author describes a series of tests on twelve octagonal columns 3.94 ft. long and 13.75 in. wide across the flats, reinforced with four or six vertical rods 1 3/16 or 1⅜-in. diameter and a spiral of 3/32-in. by ¾-in. flat steel, at 2-in. pitch. In each case two identical specimens were tested with continuous reinforcement and two similar specimens with welded bars. The results are discussed in detail. The percentage of reinforcement ranged from about 4 to 11 per cent, and the author concludes that welding the longitudinal bars reduces their efficiency by about 10 per cent.—R. SALIGER. (**Beton und Eisen*, 29, 310-312.)

Influence of Changes in the Path of Welding-Rods upon the Mechanical Strength of Welds

The author carried out a number of experiments to investigate the effect of the several welding operations. Thus, when using bare rods, the rods should advance in zig-zag paths, whereas if covered rods are used they should move forward in semicircles; otherwise the resulting slag will adhere to the edges, whence it is not easily removed during welding. Bare rods do not effect such a deep penetration into the plate as covered rods. The heated zone near welds was also studied, and the author explains that hard steels, doubtless on account of their lower melting-points, reveal wider zones than mild steels. The different effects on the tenacity, the bending qualities, and the percussion work were studied with the aid of numerous tests on ¼-in., ½-in. and ¾-in. plates. The results are roughly summarized in the following table:

		Tenacity, Tons per Sq. In. Rods			Angle at Which Cracks First Appeared, Degrees. Rods		
Welds	Currents	Bare	Covered	Washed	Bare	Covered	Washed
		Plates ¼ In. Thick					
Butt	D.C.	17	27	26	52	84	46
Butt	A.C.	20	27	23	53	89	57
V	D.C.	29	28	22	89	104	67
		Plates ½ In. Thick					
V, two layers.	D.C.	24	25	24	27	92	..
		Plates 1 In. Thick					
V, four layers	D.C.	19	23	..	30	69	..
X, six layers.	D.C.	25	27	..	37	93	..

Four qualities of covered welding rods were employed and two qualities of washed rods. The results of fifty-one percussion bending tests are given, but are difficult to summarize. The author's conclusions are that welds made with bare rods and with washed rods have numerous oxide inclusions and contain oxygen and nitrogen, and that they are not so reliable as welds made with asbestos-covered rods: with the latter care has to be taken to remove the slag during the welding operation.—K. BAUMGÄRTEL. (**Forschungsarbeiten No.* 336, 33 pp.)

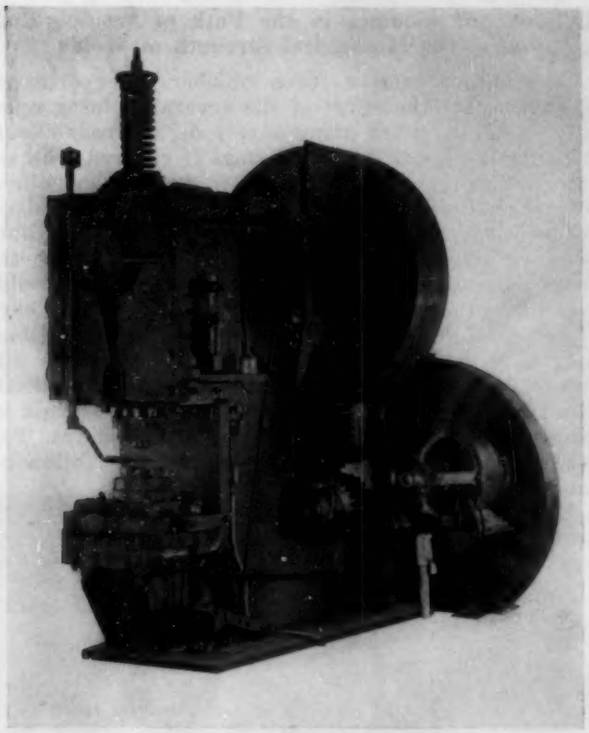
New Washer Punch Press of All-Welded Rolled Steel Construction

By EVERETT CHAPMAN

✦ Mr. Chapman is Director of Engineering & Research of Lukenweld, Inc.

IN cooperation with engineers of the development and research division of Lukenweld, Inc., of Coatesville, Pa., the Heavy Machinery and Hydraulic Equipment Department of Reading Iron Company, Reading, Pa., recently designed and built a heavy duty washer punch press with 525 tons' ram pressure, capable of cold-punching, at one stroke, complete washers up to 6 in. outside diameter and 3 in. inside diameter, from rolled steel plate up to ⅝ in. in thickness.

The press is equipped with a mechanism which ejects the punched washers from the dies, and places them on a throw-out arm from which they are deposited in a receptacle at the side of the machine. Power is provided by a 25-hp. motor with a speed range of 2 to 1 for operation at 40 r.p.m. maximum for small washers and 20 r.p.m. for large washers. The method of transmitting power from the motor to the pitman was devised to take advantage of the fact that the welded rolled steel flywheel with which the press is equipped can be run with safety at considerably higher speeds, due to the known homogeneity and uniformity of the rolled material. Higher speed operation of the flywheel permitted the use of a lighter-weight flywheel to store up the necessary energy, and effected a weight-saving which reduced some of the bearing loads—a factor of importance on a press of this type.



All-Welded Washer Punch Press

The housing and outboard bearing stand assembly, gears, pinions, flywheel and other parts of the press were fabricated by gas-cutting, forming and arc welding of rolled steel plates and slabs. A reduction of over two and one-half tons in the total weight of the press was accomplished through more efficient design and more economical distribution of metal which are possible with welded steel construction, which permits the designer to place metal only where metal is needed and eliminates the necessity of allowing for imperfections frequently found in materials other than rolled steel.

In redesigning the press for utilization of welded steel construction in important parts, particular attention was given to the study of stress concentrations. As a result, the housing and outboard bearing stand assembly (or main frame) is comparatively free from stress concentrations, and possesses the required rigidity and strength to prevent spring in the frame. The importance of this feature is realized when consideration is given to die cost and wear, and the added grindings that would be required per run if the frame did not maintain proper alignment.

The decreased weight of the press, effected by efficient design and manufacture of important parts made a worthwhile saving in press cost, while the fact that manufacture by arc welding of rolled steel required no patterns made an additional economy of several hundred dollars. The press is now in service at the plant of the By-Products Steel Corporation.

Present Practice in Rail Bonding

By **PLINEY P. PIPES**

✦Abstract of paper read before the 32nd annual convention —International Acetylene Association, Chicago, Illinois— November 11, 12, 13, 1931, by Pliney P. Pipes, Engineer, Ohio Brass Co., Mansfield, Ohio.

RAIL bonds are used for two distinct purposes; first, for carrying propulsion currents on electrified transportation systems such as: steam railroads, street railways, mines and industrial haulage; and second, for maintaining track circuits for control of railway automatic signaling.

The rapid commercial development of oxy-acetylene and electric arc welding during the past two decades has almost completely revolutionized rail bonding methods. With the oxy-acetylene torch and a copper alloy rod a bond can be applied to a steel rail very quickly, with low permanent contact resistance and good mechanical strength.

The initial installation of gas weld bonds was made on the London and Port Stanley Railroad, Ontario, Canada, in 1914, using a portable acetylene generator and compressed oxygen. The development of portable tanks of compressed acetylene, replacing the acetylene generator, was responsible for the widespread use of this process for welding and bonding on railroads.

In the early days of gas weld bonding there was naturally some question on the part of those responsible for track design and maintenance, as to the effect of such intense local heating on the structure and service life of the rail. In 1926 the Rail Committee of the American Railway Engineering Association made an exhaustive research study of this heat effect on open-hearth rail. The following is quoted from the report of that committee: "no detrimental effect results from gas welding signal or propulsion bonds to the outside head of the rail, particularly within the limits of the joint bars." The committee recommended "that the application of welded bonds to the outside head of the rail within the limits of the joint bars for *standard bonding* and outside of joint bars for *special work* where not practicable to apply them within the joint bar limits, be approved as good practice, and this recommendation printed in the Manual." Since this decision was rendered, there has been a steadily increasing use of the gas weld bond for both signal and propulsion circuits.

The gas weld bond has the advantage of low material and installation cost. Its length varies from about 7 in. to 13 in. It is applied to the rail ends, thus affording much greater broken rail protection than does a long bond around the joint bars. Being entirely exposed, inspection is easily and quickly made.

The resistance of any installed bond is almost directly proportional to its length. Moreover, the current capacity with a given temperature rise is nearly inversely proportional to its length. Knowing these facts it is evident that the short gas weld bond has very decided advantages over the longer types. The sectional area of the gas weld bond varies from approximately 4000 c.m. copper equivalent in the OBalloy-1 signal bond to 500,000 c.m. capacity in two 250,000 c.m. capacity bonds per joint for heavy rapid transit lines. Third rails of rapid transit lines are bonded to as high as 3,000,000 c.m. copper equivalent.

As an illustration of economies made possible with the gas weld bond, one large electrification originally installed around each joint two long, mechanically applied, bonds of 300,000 c.m. capacity at an installed cost of nearly $7 per joint. Later a single 4/07-in. gas weld bond was found to be better in all operating characteristics than two long bonds, and with installed cost less than $1 per joint.

From the safety standpoint in signal work the short 7-in. gas weld signal bond is outstanding. Since the bond is applied at the very ends of the rail, a break at practically any point in the rail will immediately interrupt the delicately adjusted signal circuit, giving a signal stop indication until the break is repaired. There are many records of trains being stopped due to rail ends breaking or both joint bars breaking at rail ends and allowing rail ends to separate enough to pull the gas weld bond apart and interrupt the signal circuit. There is potential danger in the use of the long mechanically applied signal bond, for such track failure might not be shown on the signal system, as a break would be shunted by the bond due to the large amount of slack in the bond as installed.

For track bonding, the standard 220 cu. ft. oxygen cylinders and 300 cu. ft. acetylene cylinders are generally used. These can be readily handled on dolly cars or specially constructed carts with very little difficulty when on regular construction work. In maintenance work the problem is met on many roads with the 100 cu. ft. capacity tanks; and some consideration is being given to use of tanks as small as 50 cu. ft.

Very little skill is required in applying a gas weld rail bond. The average workman with no previous welding experience, can successfully apply gas weld bonds with only a few hours' instruction. Naturally, as he gains experience, he improves both upon weld quality and outward appearance. The welding rod is mainly copper with a small amount of flux alloyed therein, thus making a very ductile and homogeneous weld, having a shearing strength of approximately 30,000 lb. per square inch.

The application of acetylene welding to rail bonding has strongly influenced the wider use of the process in transportation operation and maintenance. Manufacturers of welded bonds have had the best cooperation from the producers of oxygen and acetylene and of welding equipment. They have been helpful in instruction and servicing to the end that the material and process is intelligently and efficiently applied. Users of the gas weld method of bonding are profiting in distinct reduction in cost and in increased conductivity of their propulsion circuit. Application in signal work greatly increases the economical and reliable functioning of the signal track circuit, insuring practically full broken rail protection, adding an additional factor of reliability in the safe and proper functioning of all signal apparatus.

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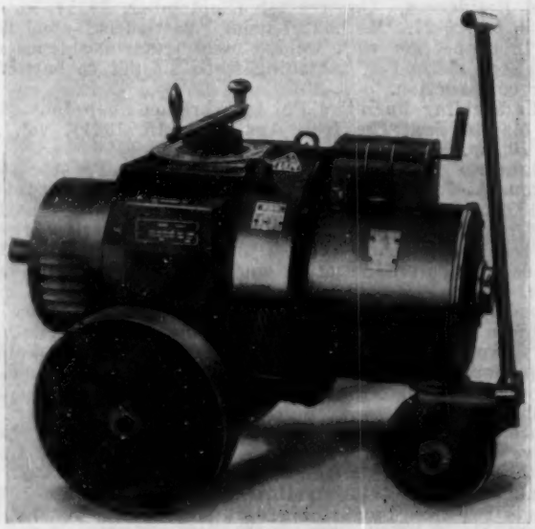

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